中華農業研究

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Gene Frequency and Genetic Variability of a Metric Character[1]

Ching Liu[2]

Abstract : This paper studies the magnitudes of the additive variance, genetic variance and the heritability in relation to the gene frequency for different degrees of dominance. The gene frequencies yielding the maximum values of additive variance, genetic variance and the heritability are also determined over a wide range of dominance. Several sizes of environmental variation have been taken into account to reflect the real-world situation. Results indicated that selection for maximizing the genetic variance or additive variance does not result in maximizing the genetic gain. It should be selected for maximizing the heritability in order to achieve the largest population improvement. A single-locus with two-allele system is considered only for the purpose of deduction, but the results derived could reprsent the average effect of a multi-loci system. The effects of epistasis, linkage, and genotype-environment interaction on the genetic variability of a metric character are briefly discussed.

INTRODUCTION

Gene freguency plays a major role in the study of quantitative inheritance of a metric character, which in turn is the foundation of genetic selection for population improvement. Gene frequency is stable in a large random-mating population in the absence of agencies tending to change its genetic properties, and selection is the most effective way in changing the gene frequency, and thus the mean and variance, in a population for the purpose of genetic improvement. Gene frequency determines the size of components of genetic variation of a metric character. It is the relative magnitude of these variation components that the genetic properties of the population are determined. Therefore, population improvement by selection is in fact changing the gene frequencies of that population.

This paper studies the magnitudes of the additive variance, genetic variance and the heritability in relation to the gene frequency for different degrees of dominance. Gene frequencies yielding the maximum values of additive variance, genetic variance and the heritability are also determined over a wide range of dominance. Several sizes of the environmental variance have been taken into account to reflect the real-world

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situation.

Throughout this paper, only a single-locus with two-allele system has been considered for the purpose of explanation and deduction. Nevertheless, the results derived could also represent the average effect of a multi-loci system [5]. Complexity arising from the dependence of genes in action (epistasis), dependence of genes in inheritance (linkage) and the genotype-environment interaction are briefly discussed.

GENE FREQUENCY AND GENETIC VARIABILITY

The genetic properties of a population may be expressed in terms of the gene frequencies and genotype frequencies. However, the concept of 'value,' expressed in the metric units, is needed in order to deduce the connection between the gene frequencies and the quantitative differences exhibited in a metric character.

The value observed when the character is measured on an individual is the phenotypic value of that individual. In order to analyze the genetic properties of the population we have to divide the phenotypic value into components attributable to different causes. The phenotypic value is first divided into components attributable to the influence of genotype and environment. Without lose of generality, we could assign arbitrary values to the genotypes for the purpose of deduction.

Following Falconer [2], values of genotypes in a two-allele system, measured as deviations from the population mean, are shown in Table 1. The average effect of a gene is the mean deviation from the population mean of individuals which received that gene from one parent, the gene received from the other parent having come at random from the population (Table 1). The genotypic values are again divided into the breeding values and the dominance deviations. The breeding value is also referred to as the 'additive genotype', and variation in breeding value called the 'additive effects' of genes. The dominance deviation arises from the property of dominance among the alleles at a locus.

As the phenotypic value can be divided into seperate components, so does the variance of phenotypic values. The components of variance and the values whose variance they measure can also be found in the last column of Table 1.

Table 1. Values of genotypes, measured as deviations from the population mean, and the variance components measuring their variances in a two-allele system.

	Genotype			Variance component
	YY	Yy	yy	
Frequency	p^2	$2pq$	q^2	—
Assigned value	a	d	$-a$	—
Genotypic value	$2q(s-qd)$	$(q-p)s+2pqd$	$-2p(s+pd)$	$Vg=2pqs^2+(2pqd)^2$
Breeding value	$2qs$	$(q-p)s$	$-2ps$	$Va=2pqs^2$
Dominance deviation	$-2q^2d$	$2pqd$	$-2p^2d$	$Vd=(2pqd)^2$
Environmental deviation	e_1	e_2	e_3	Ve
Phenotypic value	$2q(s-qd)+e_1$	$(q-p)s+2pqd+e_2$	$-2p(s+pd)+e_3$	$Vp=Vg+Ve=Va+Vd+Ve$

Environmental deviation mean : $E=0$.
Population mean : $M=a(p-q)+2dpq$.
Average effect of gene-subsititution : $s=a+d(q-p)$.

The heritability of a metric character expresses the proportion of the total variance that is attributable to the average effects of genes, and this is what determines the degree of resemblance between relatives. The most important function of the heritability in the genetic study of metric characters is its predictive role. We can only measure the phenotypic values of individuals, but it is the breeding value that determines their influence on the next generation. The heritability expresses the degree of reliability of the phenotypic value as a guide to the breeding value. The heritability is defined as the ratio of additive variance to phenotypic variance : $h^2=Va/Vp$.

In the following text the term 'gene frequency' is referred to p (see Table 1) unless otherwise specified.

1. Gene frequency yielding maximum additive variance

Since

$$Va=2pq[a+d(q-p)]^2,$$

gene frequency yielding the maximum value of additive variance may be found by partially differentiating the additive variance with respect to p (gene freguency). It is not difficult to verify that

$$p=1-[(a+4d)-\sqrt{(a^2+8d^2)}]/8d \quad \text{for } d<0,$$
$$=0.5 \quad \text{for } d=0,$$
$$=[(a+4d)-\sqrt{(a^2+8d^2)}]/8d \quad \text{for } d>0,$$

yields the maximum value of additive variance.

Gene frequencies yielding the maximum additive variances for different degrees of dominance are shown in Table 2 along with the heritabilities under various magnitudes of the environmental variance.

It can be seen that gene frequency resulting in maximum additive variance is determined by the degree of dominance (Table 2). The distribution of the additive variance in relation to the gene frequency is symmetrical when there is no dominance. But the distribution is positively skewed when there is positive dominance and negatively skewed when there is negative dominance. The maximum additive variance attainable increases along with the increase of the dominance. At the gene fregency yielding the maximum additive variance, the heritability decreases as the environmental variance increases for any given degree of dominance. When there is environmental variation present, the heritability gradually increases as the degree of dominance increases. It is noted that when there is no environmental variation, the heritability decreases as the degree of dominance increases. This is because that the gene frequency yielding maximum additive variance also increases the genetic variance and the rate of increase of the latter is faster than that of the former (Table 2).

Table 2. Gene frequency yielding maximum additive variance for different degrees of dominance (d). Heritab'lities under various magnituedes of environmental variance (Ve) are also shown. Gene frequency designates p for positive dominance and designates q for negative dominacne.

a	| d |	Gene freq.	Additive variance	Genetic variance	Heritability				
					Ve=0	Ve=50	Ve=100	Ve=200	Ve=300
10	0	0.500	50.000	50.000	1.000	0.500	0.333	0.200	0.143
10	1	0.451	50.495	50.740	0.995	0.501	0.335	0.201	0.144
10	2	0.407	51.928	52.860	0.982	0.505	0.340	0.205	0.147
10	3	0.370	54.176	56.133	0.965	0.510	0.347	0.212	0.152
10	4	0.341	57.105	60.333	0.946	0.518	0.356	0.219	0.158
10	5	0.317	60.601	65.288	0.928	0.526	0.367	0.228	0.166
10	6	0.298	64.581	70.882	0.911	0.534	0.378	0.238	0.174
10	7	0.282	68.986	77.038	0.895	0.543	0.390	0.249	0.183
10	8	0.270	73.772	83.703	0.881	0.552	0.402	0.260	0.192
10	9	0.259	78.909	90.845	0.869	0.560	0.413	0.271	0.202
10	10	0.250	84.375	98.438	0.857	0.568	0.425	0.283	0.212
10	11	0.242	90.154	106.465	0.847	0.576	0.437	0.294	0.222
10	12	0.236	96.234	114.914	0.837	0.584	0.448	0.306	0.232
10	13	0.230	102.605	123.776	0.829	0.590	0.459	0.317	0.242
10	14	0.225	109.260	133.044	0.821	0.597	0.469	0.328	0.252
10	15	0.220	116.194	142.712	0.814	0.603	0.479	0.339	0.262
10	16	0.216	123.402	152.776	0.808	0.609	0.488	0.350	0.273
10	17	0.212	130.880	163.232	0.802	0.614	0.497	0.360	0.283
10	18	0.209	138.626	174.079	0.796	0.619	0.506	0.371	0.292
10	19	0.206	146.636	185.314	0.791	0.623	0.514	0.381	0.302
10	20	0.203	154.910	196.935	0.787	0.627	0.522	0.390	0.312
10	21	0.201	163.446	208.941	0.782	0.631	0.529	0.400	0.321
10	22	0.199	172.242	221.331	0.778	0.635	0.536	0.409	0.330
10	23	0.197	181.296	234.102	0.774	0.638	0.543	0.418	0.339
10	24	0.195	190.609	247.256	0.771	0.641	0.549	0.426	0.348
10	25	0.193	200.178	260.790	0.768	0.644	0.555	0.434	0.357

2. Gene frequency yielding maximum guentic variance

Since

$$Vg=2pq[a+d(q-p)]^2+(2pqd)^2,$$

as we did for additive variance, gene frequency yielding the maximum value of genetic variance is found by taking the partial differentiation of the genetic variance with respect to p. After a little algebraic simplification and deduction, the solution is found to be :

a. $p=a[(1+d/a)/2+\sqrt{(2/3)}\cdot\cos(\theta+2\pi/3)]/d$

for $d>0$ and $d\leq\sqrt{[1+\sqrt{(32/27)}]}\cdot a$,

where $\theta=\cos^{-1}[\sqrt{(27/32)}\cdot(1-d^2/a^2)]/3$.

b. $p=a[(1+d/a)/2-\sqrt{(2/3)}\cdot\cos\theta]/d$

for $d<0$ and $d\geq-\sqrt{[1+\sqrt{(32/27)}]}\cdot a$,

where $\theta=\cos^{-1}[\sqrt{(27/32)}\cdot(d^2/a^2-1)]/3$.

c. $p=(a+d)/2d+a[\sqrt[3]{(C+D)}+\sqrt[3]{(C-D)}]/d$

for $d\neq0$ and $|d|>\sqrt{[1+\sqrt{(32/27)}]}\cdot a$,

where $C=(1-d^2/a^2)/16$ and $D=\sqrt{(C^2-1/216)}$.

d. $p=0.5$ for $d=0$

Gene frequencies which have the maximum genetic variances for different degrees of dominance are given in Table 3 along with the heritabilities under various magnitudes of the environmental variance.

Table 3. Gene frequency yielding maximum genetic variance for different degrees of dominance (d). Heritabilities under various magnituedes of environmental variance (Ve) are also shown. Gene frequency designates p for positive dominance and designates q for negative dominance.

a	|d|	Gene freq	Additive variance	Genetic variance	Hreitability				
					Ve=0	Ve=50	Ve=100	Ve=200	Ve=300
10	0	0.500	50.000	50.000	1.000	0.500	0.333	0.200	0.143
10	1	0.451	50.495	50.740	0.995	0.501	0.335	0.201	0.144
10	2	0.410	51.926	52.862	0.982	0.505	0.340	0.205	0.147
10	3	0.378	54.161	56.149	0.965	0.510	0.347	0.211	0.152
10	4	0.354	57.049	60.392	0.945	0.517	0.356	0.219	0.158
10	5	0.336	60.463	65.434	0.924	0.524	0.365	0.228	0.165
10	6	0.322	64.307	71.172	0.904	0.531	0.376	0.237	0.173
10	7	0.312	68.510	77.535	0.884	0.537	0.386	0.247	0.181
10	8	0.304	73.024	84.480	0.864	0.543	0.396	0.257	0.190
10	9	0.298	77.811	91.975	0.846	0.548	0.405	0.266	0.199
10	10	0.293	82.843	100.000	0.828	0.552	0.414	0.276	0.207
10	11	0.289	88.099	108.540	0.812	0.556	0.422	0.286	0.216
10	12	0.286	93.562	117.584	0.796	0.558	0.430	0.295	0.224
10	13	0.284	99.219	127.127	0.780	0.560	0.437	0.303	0.232
10	14	0.282	105.058	137.161	0.766	0.561	0.443	0.312	0.240
10	15	0.280	111.069	147.684	0.752	0.562	0.448	0.319	0.248
10	16	0.279	117.246	158.693	0.739	0.562	0.453	0.327	0.256
10	17	0.278	123.580	170.186	0.726	0.561	0.457	0.334	0.263
10	18	0.277	130.067	182.161	0.714	0.560	0.461	0.340	0.270
10	19	0.277	136.699	194.617	0.702	0.559	0.464	0.346	0.276
10	20	0.277	143.473	207.554	0.691	0.557	0.466	0.352	0.283
10	21	0.276	150.384	220.972	0.681	0.555	0.469	0.357	0.289
10	22	0.276	157.428	234.870	0.670	0.553	0.470	0.362	0.294
10	23	0.276	164.601	249.247	0.660	0.550	0.471	0.366	0.300
10	24	0.277	171.900	264.105	0.651	0.547	0.472	0.370	0.305
10	25	0.277	179.321	279.443	0.642	0.544	0.473	0.374	0.309

Gene frequency resulting in maximum genetic variance is also determined by the degree of dominance (Table 3) and is higher than that yielding the maximum additive variance. The distribution of the genetic variance in relation to gene freguency is, like that of additive variance, symmetrical for no dominance, positively skewed for positive dominance and negatively skewed for negative dominance. At the gene frequency yielding the maximum genetic variance, the heritability decreases as the environmental variance increases. The heritability usually increases as the degree of dominance increases, but the increasing speed under large environmental variance is higher than that under small environmental variance. When there is no environmental variance, the heritability decreases as the dominance increases, as we have seen in discussing the maximum additive variance in relation to the gene frequency. This is because the increasing rate of genetic variance is higher than that of the additive variance as the dominance increases (Table 3).

3. Gene frequency yielding maximum heritability

Heritability is expressed as

$$h^2 = Va/Vp$$
$$= 2pqs^2/(2pqs^2 + 4p^2q^2d^2 + Ve)$$
where $s = a + d(q - p)$.

Again, we partially differentiate it with respect to p to get the gene frequency which maximize (or minimize) the heritability. After simplification, the answer is found to be the relavent solution of the following equation :

$$8ad^2p^5 - 4d^2(5a+d)p^4 + 8d^2(2a+d)p^3 - 4d(ad+d^2-2Ve)p^2$$
$$-2(a+4d)Vep + (a+d)Ve = 0 \cdots\cdots \quad (1)$$

When there is no environmental variation (Ve=0), the solution to Equation 1 has the minimum value of heritability and the maximum value is always 1. Gene frequencies yielding the minimum heritabilities for different degrees of dominance under no environmental variation are listed in Table 4.

Table 4. Gene frequency yieiding minimum heritability for different degrees of dominance (d) under no environmental variance. Maximum heritability is always 1. Gene frequency designates p for positive dominance and designates q for negative dominance.

a	|d|	Gene frequency	Additive variance	Genetic variance	Heritability
10	0	—	—	—	—
10	1	0.5500	48.5150	48.7600	0.9950
10	2	0.6000	44.2368	45.1584	0.9796
10	3	0.6500	37.6786	39.5418	0.9529
10	4	0.7000	29.6352	32.4576	0.9130
10	5	0.7500	21.0938	24.6094	0.8571
10	6	0.8000	13.1072	16.7936	0.7805
10	7	0.8500	6.6326	9.8188	0.6755
10	8	0.9000	2.3328	4.4064	0.5294
10	9	0.9500	0.3430	1.0740	0.3193
10	10	1.0000	0.0000	0.0000	0.0000
10	11	0.9545	0.0000	0.9112	0.0000
10	12	0.9167	0.0000	3.3611	0.0000
10	13	0.8846	0.0000	7.0429	0.0000
10	14	0.8571	0.0000	11.7551	0.0000
10	15	0.8333	0.0000	17.3611	0.0000
10	16	0.8125	0.0000	23.7656	0.0000
10	17	0.7941	0.0000	30.9005	0.0000
10	18	0.7778	0.0000	38.7160	0.0000
10	19	0.7632	0.0000	47.1752	0.0000
10	20	0.7500	0.0000	56.2500	0.0000
10	21	0.7381	0.0000	65.9189	0.0000
10	22	0.7273	0.0000	76.1653	0.0000
10	23	0.7174	0.0000	86.9759	0.0000
10	24	0.7083	0.0000	98.3403	0.0000
10	25	0.7000	0.0000	110.2500	0.0000

On the contrary to zero environmental variation, the solution to Equation 1 gives the maximum value of heritability when there is environmental variation present. Gene frequencies yielding the maximum heritabilities for different degrees of dominance under various magnitudes of environmental variation are given in Table 5 to Table 8.

Table 5. Gene frequency yieiding minimum heritability for different degrees of dominance (d) under 50-unit of environmental variance. Minimum heritability is always 0. Gene frequency designates p for positive dominance and designates q for negative dominance.

a	|d|	Gene frequency	Additive variance	Genetic variance	Heritability
10	0	0.5000	50.0000	50.0000	0.5000
10	1	0.4505	50.4951	50.7402	0.5012
10	2	0.4038	51.9259	52.8532	0.5049
10	3	0.3618	54.1564	56.0759	0.5105
10	4	0.3256	57.0261	60.1117	0.5179
10	5	0.2948	60.3939	64.7164	0.5265
10	6	0.2690	64.1522	69.7195	0.5359
10	7	0.2472	68.2236	75.0100	0.5457
10	8	0.2287	72.5526	80.5165	0.5559
10	9	0.2128	77.0985	86.1919	0.5661
10	10	0.1991	81.8303	92.0038	0.5763
10	11	0.1872	86.7243	97.9288	0.5863
10	12	0.1767	91.7612	103.9497	0.5960
10	13	0.1674	96.9254	110.0531	0.6056
10	14	0.1590	102.2039	116.2283	0.6148
10	15	0.1516	107.5856	122.4668	0.6238
10	16	0.1448	113.0611	128.7613	0.6325
10	17	0.1386	118.6222	135.1060	0.6408
10	18	0.1330	124.2616	141.4958	0.4689
10	19	0.1278	129.9733	147.9263	0.6567
10	20	0.1231	135.7514	154.3937	0.6642
10	21	0.1187	141.5911	160.8947	0.6714
10	22	0.1146	147.4880	167.4265	0.6783
10	23	0.1108	153.4379	173.9865	0.6850
10	24	0.1073	159.4372	180.5725	0.6915
10	25	0.1040	165.4828	187.1825	0.6977

Table 6. Gene frequency yieiding minimum heritability for different degrees of dominance (d) under 100-unit of environmental variance. Minimum heritability is always 0. Gene frequency desinagtes p for positive dominance and designates q for negative dominance.

a	|d|	Gene frequency	Additive variance	Genetic variance	Heritability
10	0	0.5000	50.0000	50.0000	0.3333
10	1	0.4507	50.4951	50.7403	0.3350
10	2	0.4054	51.9277	52.8573	0.3397
10	3	0.3660	54.1714	56.1099	0.3470
10	4	0.3330	57.0848	60.2424	0.3562
10	5	0.3056	60.5468	65.0498	0.3668
10	6	0.2827	64.4646	70.3858	0.3783
10	7	0.2634	68.7692	76.1483	0.3904
10	8	0.2470	73.4093	82.2650	0.4028
10	9	0.2328	78.3458	88.6831	0.4152
10	10	0.2205	83.5480	95.3623	0.4277
10	11	0.2096	88.9913	102.2712	0.4400
10	12	0.1998	94.6551	109.3841	0.4521
10	13	0.1911	100.5221	116.6798	0.4639
10	14	0.1833	106.5772	124.1404	0.4755
10	15	0.1761	112.8072	131.7506	0.4868
10	16	0.1695	119.2005	139.4969	0.4977
10	17	0.1635	125.7465	147.3677	0.5083
10	18	0.1579	132.4356	155.3527	0.5186
10	19	0.1527	139.2592	163.4427	0.5286
10	20	0.1479	146.2093	171.6296	0.5383
10	21	0.1434	153.2786	179.9060	0.5476
10	22	0.1392	160.4604	188.2653	0.5566
10	23	0.1353	167.7485	196.7017	0.5654
10	24	0.1316	175.1370	205.2097	0.5738
10	25	0.1280	182.6206	213.7845	0.5820

Table 7. Geny frequency yieiding maximum heritability for different degrees of dominance (d) under 200-unit of environmental variance. Minimum heritability is always 0. Gene frequency designates p for positive dominance and designates q for negative dominance.

a	| d |	Gene frequency	Additive variance	Genetic variance	Heritability
10	0	0.5000	50.0000	50.0000	0.2000
10	1	0.4508	50.4951	50.7403	0.2014
10	2	0.4061	51.9282	52.8589	0.2054
10	3	0.3681	54.1751	56.1230	0.2115
10	4	0.3368	57.0997	60.2929	0.2194
10	5	0.3112	60.5871	65.1820	0.2285
10	6	0.2901	64.5509	70.6590	0.2385
10	7	0.2726	68.9279	76.6335	0.2492
10	8	0.2577	73.6726	83.0417	0.2603
10	9	0.2450	78.7506	89.8368	0.2717
10	10	0.2339	84.1362	96.9831	0.2833
10	11	0.2242	89.8088	104.4521	0.2950
10	12	0.2155	95.7517	112.2200	0.3067
10	13	0.2078	101.9508	120.2666	0.3183
10	14	0.2007	108.3941	128.5741	0.3299
10	15	0.1943	115.0708	137.1269	0.3413
10	16	0.1884	121.9712	145.9105	0.3526
10	17	0.1829	129.0865	154.9118	0.3637
10	18	0.1779	136.4084	164.1188	0.3746
10	19	0.1731	143.9291	173.5203	0.3853
10	20	0.1687	151.6413	183.1058	0.3958
10	21	0.1645	159.5379	192.8658	0.4061
10	22	0.1606	167.6124	202.7909	0.4161
10	23	0.1569	175.8582	212.8729	0.4259
10	24	0.1533	184.2693	223.1036	0.4355
10	25	0.1500	192.8398	233.4755	0.4449

Table 8. Gene frequency yieiding maximum heritability for different degrees of dominance (d) under 300-unit of environmental variance. Minimum heritability is always 0. Gene frequency designates p for positive dominance and designates q for negative dominance.

a	| d |	Gene frequency	Additive variance	Genetic variance	Heritability
10	0	0.5000	50.0000	50.0000	0.1429
10	1	0.4509	50.4951	50.7403	0.1440
10	2	0.4064	51.9282	52.8594	0.1472
10	3	0.3688	54.1758	56.1267	0.1521
10	4	0.3381	57.1025	60.3075	0.1585
10	5	0.3131	60.5948	65.2205	0.1659
10	6	0.2927	64.5676	70.7394	0.1742
10	7	0.2758	68.9594	76.7783	0.1830
10	8	0.2616	73.7262	83.2773	0.1924
10	9	0.2495	78.8356	90.1933	0.2020
10	10	0.2390	84.2634	97.4935	0.2120
10	11	0.2298	89.9910	105.1525	0.2221
10	12	0.2217	96.0036	113.1490	0.2324
10	13	0.2144	102.2891	121.4651	0.2427
10	14	0.2078	108.8372	130.0853	0.2531
10	15	0.2018	115.6391	138.9954	0.2634
10	16	0.1963	122.6870	148.1826	0.2737
10	17	0.1913	129.9735	157.6350	0.2840
10	18	0.1866	137.4922	167.3417	0.2942
10	19	0.1822	145.2367	177.2920	0.3043
10	20	0.1781	153.2011	187.4762	0.3143
10	21	0.1742	161.3798	197.8848	0.3241
10	22	0.1705	169.7672	208.5088	0.3339
10	23	0.1671	178.3580	219.3398	0.3434
10	24	0.1638	187.1470	230.3695	0.3529
10	25	0.1607	196.1291	241.5900	0.3621

Magnitude of the heritability in relation to the gene frequency for different degrees of dominance under no environmental variance can be seen in Fig. 1. When there is no environmental variance, only the minimum heritability exists. The maximum heritability does not exist if the gene frequency is not fixed. Gene frequency yielding the minimum heritability is larger than 0.5 for positive partial dominance and is smaller than 0.5 for negative partial dominance (Table 4). Gene frequency resulting in minimum heritability gradually shifts to 0.5 from the right with the increase of positive overdominance and to 0.5 from the left with the increase of negative overdominance.

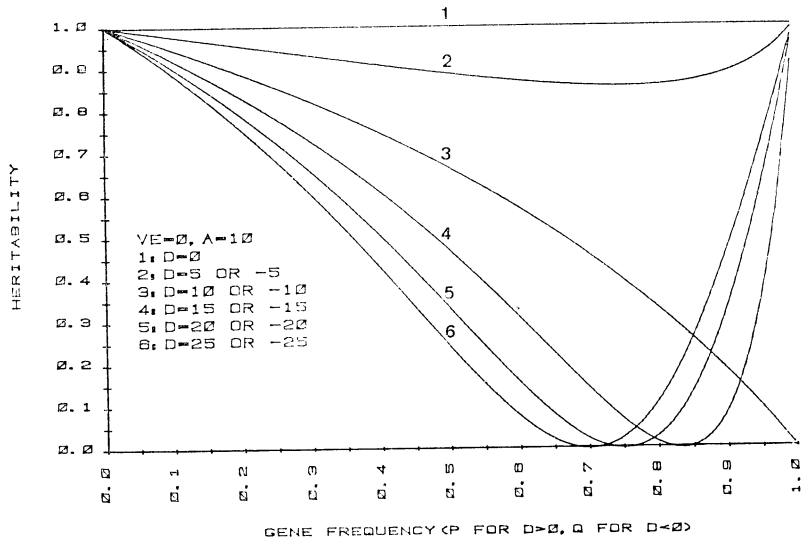

Fig. 1. Magnitude of heritability in relation to gene frequency for different degrees of dominance (D) under no environmental variance (VE).

When there is environmental variance present, and this is usually the case, the solution to Equation 1 gives the maximum heritability. Magnitude of the heritability in relation to the gene frequency for different degrees of dominance are plotted in Fig. 2 (for 50-unit of environmental variance), Fig. 3 (for 100-unit of environmental variance), Fig. 4 (for 200-unit of environmental variance)and Fig. 5 (for 300-unit of environmental variance).

From these figures, along with Table 5 to Table 8, we can see that for a given degree of environmental variance, the gene frequency that maximizes the heritability shifts from 0.5 to the left with the increase of positive dominance and shifts from 0.5 to the right with the increase of negative dominance. The maximum attainable heritability increases with the increase of dominance. It is interesting to note that when overdominance occurs, the distribution of heritability in relation to the gene frequency is a bi-modal one with higher peak on the left for positive overdominance and with higher peak on the right for negative overdominance.

For a given degree of dominance, gene frequencies resulting in maximum genetic variance (Table 3), maximum additive variance (Table 2) and maximum heritability

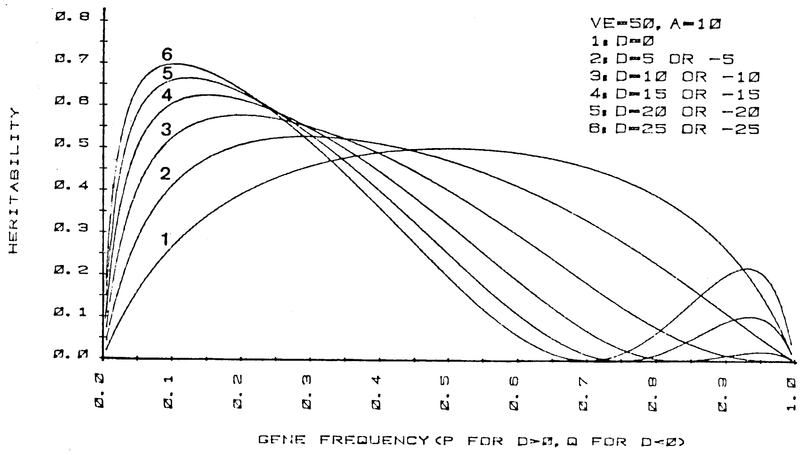

Fig. 2. Magnitude of heritability in relation to gene frequency for different degrees of dominance (D) under 50-unit of environmental variance (VE).

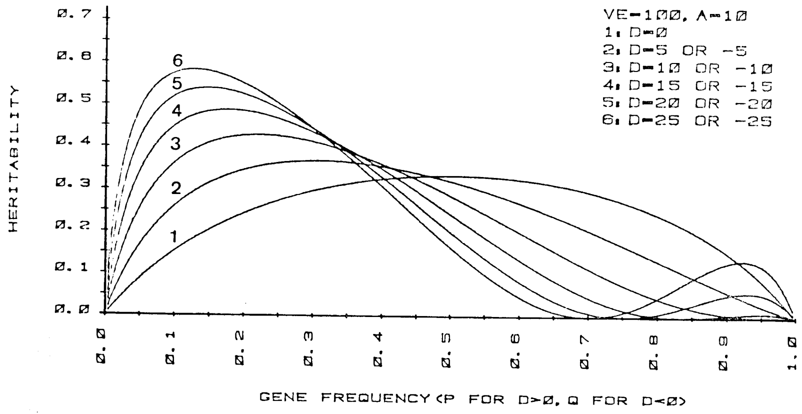

Fig. 3. Magnitude of heritability in relation to gene frequency for different degrees of dominance (D) under 100-unit of environmental variance (VE).

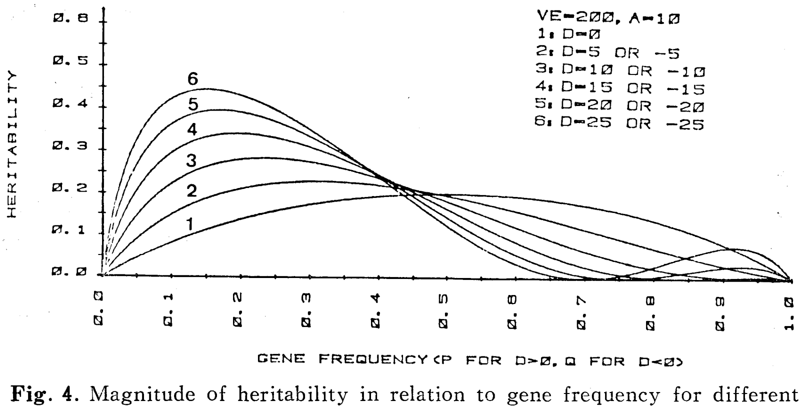

Fig. 4. Magnitude of heritability in relation to gene frequency for different degrees of dominance (D) under 200-unit of environmental variance (VE).

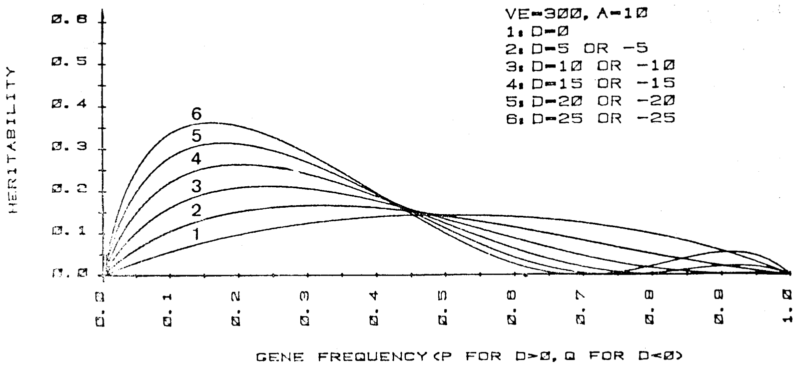

Fig. 5. Magnitude of heritability in relation to gene frequency for different degrees of dominance (D) under 300-unit of environmental variance (VE).

(Table 5 to Table 8) are in decreasing order for positive dominance and are in increasing order for negative dominance. This indicates that selection for maximizing the genetic variance or additive variance does not result in maximizing the genetic gain. It should be selected for maximizing the heritability in order to achieve the largest population improvement.

DISCUSSION

The contributions to the genetic variation of gene pairs at different loci are additive, in the way assumed in this paper, only if the genes at various loci are independent in both action and inheritance. Independence in action means that the increment added to a metric character in question by the substitution of one allele for another at a given locus is unaffected by the remaining genes under consideration. Dependence of genes in action means epistasis [5]. Throughtout this paper we confined our discussion to a single-locus with two-allele system. But the genetic variation of metric characters is in reality the product of segregation at some hundreds or thousands of loci. When only a single locus is considered the genotypic value is made up of the breeding value and the dominance deviation only. But when the genotype refers to more than one locus the genotypic value may include the epistatic deviation due to non-additive combination. In practice we can seperate the additive variance from the rest of the genetic variance, and so make the partition into additive, non-additive and environmental variance, $Vp = Va + (Vd + Vi) + Ve$, the dominance and interaction components being put together as non-additive variance. However, the amount of variance contributed by epistatic deviation is usually rather small and the neglect of it is therefore not likely to lead to serious error [2].

Independence of genes in inheritance means that the two alleles at one locus are equally likely to be transmitted from parent to offspring together with a given allele at the second locus. Dependence of genes in inheritance means linkage [5]. When the genes in question have no effects on viability, linkage does not affect the frequencies with which the alleles of each gene pairs are recovered in segregating generations [1]. Al-

though linkage does have its effect in partitioning the genetic variation, the effect of linkage on the value of a statistic could be zero even though linkage was in fact present; for the coupling and repulsion items, as well as the reinforcement and opposition items, could balance and thus cancel out [4,5]. The effect of linkage in partitioning the genetic variance will most probably render the dominance variance to include some of the interaction variance caused by linkage.

Another assumption we have made is that a specific difference of environments has the same effect on different genotypes. If this assumption is not justifiable, there is an interaction between genotypes and environments. An interaction between genotype and environment gives rise to an additional component of variance. This interaction variance can be isolated and measured by replicating genotypes under several different environments. Then an analysis of variance in a two-way classification of genotype×environment will yield estimates of the genotypic variance, the environmental variance and the genotype-environment interaction variance. In most cases the interactions are small relative to the genotypic and environmental effects and the interaction with heterozygotes genotypes is smaller than that with homozygotes in segregating generation [3,6]. Therefore, the variance due to genotype-environment interaction is best regarded as part of the environmental variation in the genetic study of a population unless differences of environments are under consideration, then the presence of genotype-environment interaction become important in connection with the specialization of breeds or varieties to local conditions.

A mathematical description of the complex genetic situation results in equations too cumbersome for solution. The Monte Carlo simulation by high-speed computer does not seem satisfactory either, due to too many subjectively assigned conditions. Although simple genetic model may lead to some departure from reality in the study of quantitative genetics, it is needed for the purpose of deduction. What we have previously discussed is the general effects of epistasis and linkage arising from a multi-loci system. and interaction between genotype and environment; detailed examination of these effects on the genetic variability of a me ric character is to be made case by case.

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數量性狀之基因頻度與遺傳變異[1]

劉 清[2]

摘 要

本文探討在不同顯性程度下，基因頻度與累加性變方，遺傳變方及遺傳率之關係，導出形成最大累加性變方，遺傳變方及遺傳率之基因頻度值，並考慮不同程度之環境變異對其所產生的影響。結果顯示使遺傳變方或累加性變方爲最大之選拔並未能導致最大之遺傳獲得，只有使遺傳率爲最大之選拔方能造成最大之族羣改良。本文以一對基因之情況來描述基本遺傳系統並導出必要公式，所得推論亦可視爲多因子系統之一般結果。上位性作用，連鎖作用及遺傳一環境交感作用對一數量性狀遺傳變異之影響亦曾加討論。

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Biomass Yield, Juice Quality and Alcohol Production of Sweet Sorghum

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Abstract : Cultivation of energy crops under the normal conditions to produce biomass energy is thought to be one of the important ways to develop substitute energy. The present experiment was conducted to detect the biomass yielding capacity, juice physicochemical properties and the alcohol productivity of the selected sweet sorghum line AM-4 , and to evaluate its possible value as an energy crop.

The results showed that AM-4 had high biomass yield (44.4—46.1 t/ha), brix value (18.2—23.2) and sucrose content (11—12%), short growth period (four months) and wide adaptability. Results from the fermentation test indicated that alcohol production rate higher than 9% can be obtained through the juice fermentation with either *S. cerevisiae* or *Sf* yeast strain at 30°C within two days. The needed temperature can be easily achieved by the use of the abundant solar radiation in Taiwan. Therefore the input cost can be reduced considerably.

Introduction

Although the oil prices decreased, it doesn't mean that the energy crisis is over. The development of substitute energy resources such as biomass energy is still an important goal of research work in many countries (10).

Sweet sorghum, a promising biomass resource with high sugar content, has good adaptability, high yield and short growth period (1,7,8). Its juice can be directly used for alcohol production (3). This advantage for energy use has been recognized during the past years. The Department of Energy of the U. S. A. estimated that after 1990 sweet sorghum can top all crops such as cereals and sugar-cane as the best resource for alcohol production (2,3,11). The national alcohol production program of Brazil has also selected sweet sorghum together with sugar-cane and cassava as the three main biomass resour-

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ces for ethanol production[4]. After having been introduced and tested in Taiwan, a few sweet sorghum varieties with short growth period, high yield and high sugar content have been selected[1,8]. The main purpose of this study was to determine the efficiency of alcohol production from the best sweet sorghum line, AM-4, and to find out the useful yeast strains and their appropriate reaction conditions.

Material and Methods

1. Material :

AM-4, a high yield sweet sorghum line introduced from the U. S. A. by Taichung District Agricultural Improvement Station, has been under cultivation in Taichung since 1981, in Wujih since 1983, and in Houli since 1983. The planting time was in fall 1981 and in spring 1983. The growing distance was 60×30 cm in Taichung area and 50×10 cm in Wujih and Houli area.

2. Methods :

The following characteristics are determined individually :

Density value : 100 ml of AM-4 juice was weighed and the density was expressed in g/ml. A total of 8 replications was determined and the mean value was presented.

Brix degree : The brix degree of AM-4 juice was determined with a Shimadzu refractometer.

Refraction rate : Take 2-3 drops of AM-4 juice and the refraction rate was determined with a Shimadzu refractometer.

Viscosity value : Take 100 ml AM-4 juice and determine the viscosity value from 16°C to 90°C with the Brookfield LVT viscosimeter.

Total nitrogen : Two ml of AM-4 juice were digested with concentrated H_2SO_4 with $CuSO_4$ and K_2SO_4 as catalysts. After digestion, the volume was made to 100 ml and 10 ml of the diluted solution was then distilled with 5 ml of 40% NaOH. Total N could be obtained by titrating with 0.01N HCl.

Sucrose content : Dilute the AM-4 juice 10 times and to 50 ml diluted juice add N/10 HCl, then heat it in the water bath. Neutralize the solution with N/10 NaOH and dilute to 250 ml. Take 1 ml of the diluted solution to determine the reducing sugar content with the Somogyi method and calculate the sucrose content with formula.

Reducing sugar content : Dilute the AM-4 juice 10 times and take 1 ml to determine the sugar content with the Somogyi method.

Moisture content : Heat the AM-4 juice at 105°C under normal pressure until constant weight is reached.

Determination of the amino acids : Take the dry AM-4 samples and put together with 10 times quantity of 6N HCl into the test tube. Close the gap under vacuum and heat it at 110±2°C for 24 hours. After drying add 0.05M sodium citrate buffer and

filtrate through a 0.2μ pore membrane. Then take 1-2 n mole sample to determine the amino acid composition with the amino acid analyzer.

Fermentation: Take 50 ml of AM-4 juice and add 1 gram of yeast (*Saccharomyces cerevisiae*). After adjusting the PH-value to 5.5 with H_3PO_4, put the solution into the incubator at 30°C. The other yeast strains tested are S290 , S24, S21 and Sf.

Ethanol determination: The ethanol rate was determined with a Shimadzu FID GC under the following conditions: Injection temperature 170°C, column 150°C, FID detector 200°C, N_2 speed 40 ml/min, air pressure 0.9 kg/cm^2, H_2 pressure 1 kg/cm^2, range 0.01v 256, sensitivity MΩ 10^2. Sample quantity in liquid form was 1 μl. Before determining the ethanol rate the fermented solution should be centrifugated at 15,000 rpm for 20 minutes.

Result and Discussion

I. Stalk yield and the juice properties of sweet sorghum

Two cultural improvements, early planting in spring and narrow spacing, have increased the stalk yield of the AM-4. Highest yield of 44.4 t/ha is obtained in Wujih area and 46.1 t/ha in Houli area. The juice brix degree has also been increased from 12.5 to 18.2 degree (Wujih area) and to 16.1 degree (Houli area) (Table 1). These results have topped those of the U. S. A. and previous results obtained in Taiwan[8,11,12]. Am-4 has its highest brix degree up to 23.24 (Table 2). Therefore, AM-4 can be thought as a promising biomass producing source.

Table 1. Stalk yield and brix degree of sweet sorghum AM-4

Location	Planting Season	Spacing (cm)	Stalk yield (t/ha)	Brix degree
Taichung	fall, 1981	60×30	11.71	12.50
Taichung	spring, 1983	60×30	31.86	16.50
Wujih	spring, 1983	50×10	44.43	18.20
Houli	spring, 1983	50×10	46.08	16.10

The average growth period of sweet sorghum, including AM-4, is four months. It is 8-14 months shorter than that of cassava and 14 months shorter than that of sugarcane. The total energy inputs of sweet sorghum are 4,011 Mcal/ha, being the lowest of these three energy crops[4].

The juice of different sweet sorghum varieties possesses different physical and chemical characters. The physical properties of the AM-4 juice are analyzed and shown in Table 2. The brix degree ranges from 12.50 to 23.24 with an average value of 16.94. The density value is 1.06 g/ml, being higher than those of water (1.00), alcohol (0.79)

and gasoline (0.72-0.78). The average refraction index of AM-4 is 1.36. This is proportional to the brix degree and the density value (Table 2). At 16°C the average viscosity value is 6.55, which is almost two times of the value at 90°C. This means the viscosity value of AM-4 is inversely proportional to the temperature (Fig. 1).

Table 2. Physical properties of AM-4 sweet sorghum juice

Physical property	Mean	Max.	Min.	Difference
Brix (degree)	16.94	23.24	12.50	10.74
Density (g/ml)	1.06	1.08	1.03	0.03
Refraction	1.36	1.36	1.35	0.01
Viscosity(centipoise at 16°C)	6.55	7.20	5.50	1.70

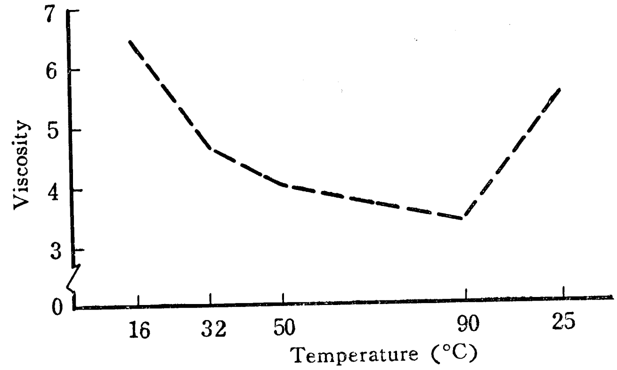

Fig. 1. Effect of heating temperature on the relative viscosity of sweet sorghum AM-4

The chemical analysis of AM-4 juice shows the following results. The highest component is the moisture with a content of 87.9% (86.1-89.3%). The sucrose content is 11.1% with a difference of 3.4%. The average reducing sugar content is 0.38% (0.31-0.56%). The average value of the total N is 0.045% (Table 3).

Table 3. Chemical composition (%) of sweet sorghum AM-4 juice

Chemical composition	Mean	Max.	Min.	Difference
H_2O	87.890	89.280	86.110	3.170
Sucrose	11.124	11.575	8.177	3.398
Reducing sugar	0.377	0.565	0.307	0.255
Total N	0.o45	0.066	0.032	0.034

The amino acid composition of the AM-4 juice is also tested with an amino acid analyzer. Content of asparagine is highest (39.3%), followed by glutamine (14.4%) and alanine (8.6%). Lowest contents (about 0.37%) are found in cysteine and methionine.

Out of the 8 essential amino acids, 7 can be detected. Only tryptophan is absent. Values of the other amino acids are between those of alanine and methionine(Table 4). The amino acid content of sweet sorghum juice can be lower or higher, depending on the test methods and the different varieties[3].

Table 4. Amino acid composition of AM-4 Juice

Amino acid	Mean (%)	Max. (%)	Min. (%)	Difference
Asparagine	39.32	43.95	34.39	9.56
Glutamine	14.38	16.31	12.35	3.96
Alanine	8.55	10.48	7.26	3.22
Serine	5.85	6.82	5.25	1.57
* Valine	5.72	6.34	5.35	0.99
* Leucine	4.97	5.78	4.24	1.54
* Isoleucine	4.45	5.31	3.36	1.95
Glycine	4.38	5.11	3.48	1.63
* Threonine	4.09	4.61	3.71	0.90
Histidine	2.70	3.13	2.29	0.84
Arginine	1.75	2.06	1.50	0.56
* Phenylalanine	1.47	2.83	0.70	2.13
* Lysine	1.44	2.35	0.73	1.62
Tyrosine	1.12	1.68	0.58	1.10
Proline	0.90	...	...	...
Cysteine	0.38	...	...	...
* Methionine	0.37	...	...	...

* essential amino acid

II. The alcohol fermentation of sweet sorghum juice

Sweet sorghum juice is rich in sugar content and can be easily used for alcohol production. It is easier to use sweet sorghum than to use cassava, potato, sweet potato[9] or other starchy crops for producing alcohol. The ethanol rate, obtained from the AM-4 juice by using *Saccharomyces cerevisiae*, is affected by the pH value of the reaction medium and the reaction temperature. Under optimal pH value of 5.5, the ethanol rate reaches 10.27% and the ethanol concentration reaches 81.5 g/l. If the pH value is higher or lower the ethanol rate will be negatively affected. The optimal temperature is 30°C, where *S. cerevisiae* can produce the highest ethanol rate (10.75%) and ethanol concentration(85.4 g/l). The alcohol production is inversely proportional to the temperature. For example, if the temperature is over 55°C, the ethanol rate decreases rapidly. At a temperature of 30°C and a pH value of 5.5, yeast strain *Sf* can also produce a high ethanol rate (above 9%). The other yeast strains such as S21, S290, and S24 can produce an

ethanol rate around 7% (Table 5,6 and 7).

Table 5. The effect of pH values on the alcohol production of AM-4 juice[a]

Yeast strain	pH	Ethanol rate (%)	Ethanol conc. (g/l)
Saccharomyces cerevisiae	3.5	3.18	25.3
	4.5	7.81	62.0
	5.5	10.27	81.5
	6.5	7.96	63.2

a The reaction temperature was 35°C

Table 6. The effect of temperatures on the alcohol production of AM-4 juice[a]

Yeast strain	Temperature (°C)	Ethanol rate (%)	Ethanol conc. (g/l)
Saccharomyces cerevisiae	30	10.75	85.4
	35	9.43	74.9
	45	3.61	28.7
	55	0.91	7.2
	65	0.61	4.8

a pH of the reaction medium was 5.5.

Table 7. The effect of various yeast strains on the alcohol production of AM-4 juice[a]

Strain	Day	Ethanol rate (%)	Ethanol conc. (g/l)
Saccharomyces cerevisiae	1	9.06	71.9
	2	9.35	74.2
S 290	1	2.75	21.8
	2	7.04	55.9
S 24	1	2.56	20.3
	2	6.99	55.5
S 21	1	2.72	21.6
	2	7.57	60.1
Sf	1	3.04	24.1
	2	9.14	72.6
Control	1	0.01	0.1
	2	0.01	0.1

a Reaction temperature was 30°C and pH of the medium was 5.5.

The sugar concentration of the fermentation solution must not be too low, otherwise the yeast propagation will slow down and the alcohol production rate will decrease[2,3]. Th esugar concentration of AM-4 juice is between 10% and 12%, which is beneficial for yeast growth and alcohol production. With the fixed yeast quantity of 1g, the ethanol production rate of a 10% sugar concentration juice reaches 8.84%. With a sugar concentration below 6%, the ethanol rate decreases significantly. At 4% the ethanol rate is only 1/6 of that of 10% sugar concentration (Table 8).

The effect of various yeast quantities on the fermentation of AM-4 juice is shown in Table 9. With 1g of *S. cerevisiae* the ethanol production rate reaches 9.41%, which is the best result among the other yeast quantities tested. However, the yeast quantity does not significantly influence the ethanol production rate of AM-4 juice (Table 9).

Table 8. The effect of different sugar concentrations of AM-4 juice on the ethanol production rate[a]

Sugar conc. (%)	Ethanol production rate (%)
10	8.84
8	7.24
6	4.93
4	1.54
2	1.11

a Ucsing 1 g of *S. cerevisiae* for 50 ml of juice.

Table 9. The effect of various yeast quantities on the ethanol production rate of AM-4 juice[a]

S. cerevisiae (g)	Ethanol production rate (%)
1	9.41
2	8.88
3	9.27
4	8.54
5	8.82

a Sugar conc. is 10%.

The relation between the ethanol production rate and the brix degree of the sweet sorghum juice has been intensively studied. In Wujih area AM-4, cultivated in three planting densities, is analysed and a relation of $r=0.9952$ and a regression of $\hat{y}=1.6849x-1.9865$ are found. Here $\hat{y}=\%$ alcohol and x =brix degree. In Taichung area ther elationship of six different sweet sorghum varieties including AM-4 is as follows: $r=0.8585$ and $\hat{y}=0.6949x-3.1927$. Furthermore, 13 other sweet sorghum lines with four replications are also studied and a relation of $r=0.9384$ and a regression of $\hat{y}=0.66226x-2.61642$ are established. A highly significant relation exists between the brix degree of

the juice and the ethanol production rate. With the brix degree known the ethanol production rate of sweet sorghum can be estimated. Increasing one brix degree can produce 0.66% more absolute ethanol (Fig. 2).

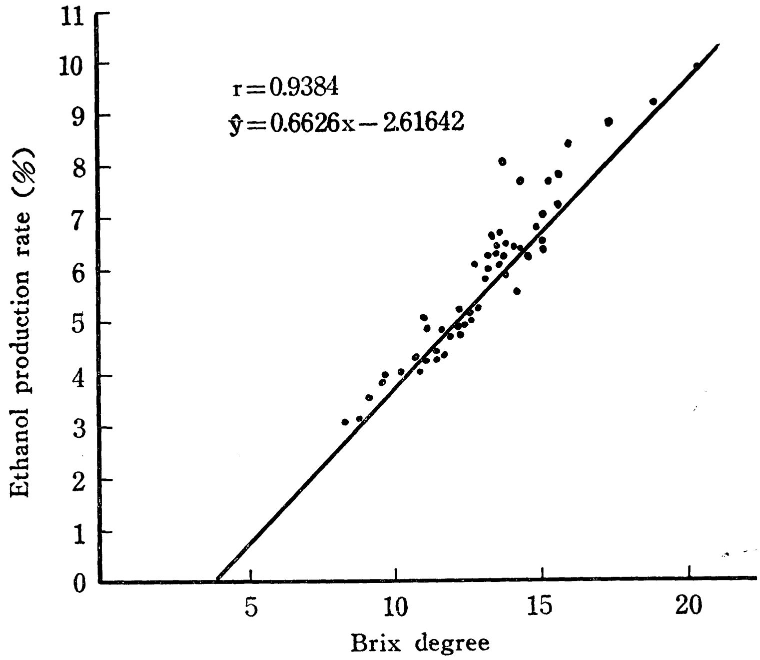

Fig. 2. Relationship between ethanol production rate and brix in sweet sorghum juice

To evaluate the output-input coefficient from the alcohol production of sweet sorghum, several references are taken into account. The agricultural costs of sweet sorghum AM-4 is the same as that of grain sorghum (5,6). The juice production cost is calculated on the basis of using small scale pressing machines. The fermentation and distillation costs are based on the information source of Lipinsky *et al.* (cf,13). The liter absolute alcohol costs NT $400. The seed cost per kg is NT$14. The bagasse costs NT$1,000 per ton. According to these informations the total input is NT$301,818/ha and the total outpt is NT$435,000/ha. The main input item is the cost of fermentation, being 59.3% of the total input costs. And the main output item is the ethanol production (84.4%) (Table 10).

Table 10. Estimated total input and output for alcohol production of sweet sorghum AM-4

Item	NT$/ha	%
Input		
Agricultural costs	57,313	18.99
Juice production process	65,527	21.71
Fermentation & Distillation	178,978	59.30
Total input	301,818	100.00
Output		
Ethanol production	367,000	84.37
Seed production	28,000	6.44
Bagasse production	40,000	9.19
Total output	435,000	100.00

The output-input coefficient is 1.44 for sweet sorghum and 1.15 for grain sorghum [6]. That means NT$1.44 can be gained if NT$1.00 is invested for the alcohol production from sweet sorghum. The hectare profit of alcohol production from sweet sorghum is nearly 16 times as high as that from grain sorghum (Table 11).

Table 11. The output/input coefficient of sweet sorghum and grain sorghum

Sorghum Type	Output (NT$/ha)	Input (NT$/ha)	coefficient
Sweet sorghum	435,000	301,818	1.44
Grain sorghum	65,814	57,313	1.15

Conclusion

The juice of AM-4 stalk contains enough sucrose and reducing sugars and can be used as a suitable solution for alcohol fermentation with *S. cerevisiae*. Besides *S. cerevisiae* yeast strain Sf can also produce more than 9% ethanol rate within two days. This means that more than 90 ml absolute alcohol can be obtained from one liter of juice. The needed temperature for *S. cerevisiae* is 30°C, which can be easily achieved by using the abundant solar energy in Taiwan. Using good sweet sorghum lines such as AM-4 and good yeast strains, it is possible to develop an alcohol industry here in the near future.

The alcohol yield per hectare of AM-4 juice found in this study amounts only 918.8 liters, while the result of the American Battele Institute is 3,554 l [2]. The possible difference between these two results is the quantity of the produced juice, which runs up to only 18-20% of stalk biomass by small scale pressing machines used in this study, but it can be as high as 60-80% if large scale juice production methods taken in sugarcane factories are used. If these methods would be used for sweet sorghum in Taiwan, the alcohol yield per hectare could excess the niveau of the U. S. A. Furthermore, the costs for fermentation and distillation can be decreased through the improvement of new yeast strains and new fermentation techniques such as yeast cell immobilization and the automatic control, etc.

Acknowledgment

This study was supported in part by a grant from the Council for Agricultural Planning and Development, Executive Yuan, R. O. C.. We thank Mr. C. Y. Chen from NTU specially for contributing many yeast strains and Dr. C. Liu for his help in statistial analysis. We are also grateful to Dr. S. C. Hsieh, and Dr. T. C. Lee for their valuable advices.

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甜高粱生質產量
莖汁品質與酒精生成潛力之研究[1]

劉新裕[2] 梁純玲[2] 陳廷煥[3]

摘 要

能源作物能在短時間內與常溫常壓下生生不息地吸收儲存太陽能量，是各國在尋求替代能源時的重要研究發展方向之一。本研究將就一優良甜高粱品系AM-4之生質生產量，莖汁理化性質及其酒精生成潛力來評估它在本省成爲優良能源作物的可能性。

由試驗結果顯示，AM-4具有下列特點：豐富的生質產量（44.4—46.1t/ha）甚高的錘度（18.2—23.2）及蔗糖量（11.0—12.0%），生育日數不長（4個月），廣大的適應能力，以及其汁液能被直接利用來生產酒精，且由其莖汁酒精醱酵結果得知，至少有兩種酵母菌株(*S. cerevisiae* 及 *S. f.*）能利用 AM-4 汁液在兩天之內生產9%以上的高酒精率，而所須溫度只 30°C，將由於利用本省無時不有的太陽能而大幅降低其酒精生產費用。由上觀之，AM-4 在本省將成爲一優良的酒精生產原料來源。

1.臺灣省農業試驗所 研究報告第 1164 號，本研究承行政院農業發展委員會補助，特此申謝。

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3.臺中區農業改良場助理研究員。臺灣省 彰化縣 大村鄉。

中華農業研究 (Jour. Agric. Res. China) 33(3)：247～256 (1984)

大豆植株營養要素之累積與分佈

I. 全生育期非構造性碳水化合物與氮素濃度之變化[1]

王強生　魏夢麗　劉大江[2]

摘要：本試驗以高雄3號 (Kaohsiung No. 3) 與十石 (Shih-Shih) 二大豆品種爲材料，測定重要生育期植株各部位 (葉片、葉柄、莖桿、根、莢果壁與種子) 非構造性碳水化合物 (TNC) 與氮素濃度，探討春 (1982)、夏 (1981) 作大豆由於此二重要營養要素濃度之變化所代表之生理意義及與產量之關係。試驗結果顯示春作大豆營養器官於種子迅速充實期前均有較高的TNC濃度，而於種子迅速充實後大幅下降，成熟時各部位TNC濃度反較夏作低，顯示春作大豆對營養器官所貯存TNC的依賴程度較大，可能是因爲春作大豆葉片較早老化、脫落而導致現階段光合生產不足，TNC之供給成爲產量的限制因子。

除葉柄外，春作各營養器官亦有較高N濃度，尤以營養生長期之差異較大。與TNC相同，各營養器官N濃度在種子充實期有大幅下降及N素再轉移現象存在。對老化即將脫落的葉片進行分析發現，夏作N素濃度皆在2.5%以上，春作更高達3.5%，顯示葉片內大量的N素無法充分轉移至種子，而此時TNC濃度已低於5%，無助於維持葉片生理活性，因而首先提出假說，認爲除TNC外，可能尚有其他未知因子誘使葉片提早老化，並阻礙N素之轉移而降低種子產量。同一期作二品種之TNC及N素濃度變化頗一爲致，而期作間差異則大，顯示兩項營養要素之累積與分佈易受環境因子之影響。

非構造性碳水化合物 (total non-structural carbohydrates, TNC) 又稱爲有效性碳水化合物，可直接參與代謝轉移、貯藏及構成組織等作用，對絕大多數的作物而言，TNC更是植株生長和發育的主要能量來源。Terman[25] 認爲大豆在生殖生長過程中，TNC供源與TNC積儲間之相互作用直接影響各種代謝反應及種子產量；Dunphy and Hanway[7] 指出大豆於種子充實期，莖桿和葉柄TNC濃度顯著下降，TNC之供給成爲產量限制因子。Huang *et al.*[12] 發現R6期，大豆根部及根瘤TNC濃度降低，固氮能力亦顯著下降，可能是TNC之生產與供給受到限制所致，Kawai and Kumagawa[14] 亦指出大豆根部TNC濃度和固氮能力及根瘤形成 (nodulation) 有密切關係。

大豆種子含大量蛋白質 (33.1～49.2%)[13]，故對N素之需求極大。Sinclair and de Wit[19] 指出大豆需要大量氮素以供種子充實之需，如果氮素供應不足，則植株營養器官所貯存的氮素會轉移至發育中的種子，而葉片氮素向外轉移又可能促使葉片提早老化[19]。Boote *et al.*[4] 指出大豆葉片氮素濃度和光合作用能力成正相關($r=0.87$)，當氮濃度自4.5%降至1.75%時，葉片光合速率由1.11 mg/m^2•sec降至0.28 mg/m^2•sec；此外Sesay and Shibles[17] 及Wittenbach *et al.*[28] 亦發現大豆葉片氮素濃度及光合能力有密切關係存在。Lugg and Sinclair[15] 更指出葉片可以貯存較多氮素的大豆品種，可以維持較高光合速率，但是Welch *et al.*[27], Brevedan *et al.*[5] 及Sorenson and Penas[21] 等發現增施氮肥並不一定提高大豆產量，顯然大豆體內氮素同化作用及產量間的關係

1.臺灣省農業試驗所 研究報告第 1165 號。本文係第一作者在中興大學糧食作物研究所碩士論文之一部份。

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並不單純。

本研究室對大豆全生育期乾物質累積的試驗結果顯示，春、夏作大豆產量之差異主要在於乾物質生產與分配效率之高低[1]。因此進一步測定不同期作大豆全生育期植株各部位 TNC與N素之濃度，比較期作間此二營養要素濃度變化之差異，探討其生理意義及與產量之關係，並試由植株營養狀況說明最終產量差異之原因。

材料與方法

試驗採用本省現行推廣大豆品種十石(Shih-Shih, SS)及高雄3號 (Kaohsiung No. 3, KS-3)爲材料，夏作係於民國70年8月3日，春作於71年2月8日播種於臺中縣霧峰鄉臺灣省農業試驗所試驗田，試驗採用逢機完全區集設計(RCBD)，小區面積 6×3 m^2，重複6次。田間管理及取樣方法如前文[1]所述，大豆生育期係依 Fehr and Caviness[10] 之方法鑑定，自田間取得之樣品區分爲葉片、葉柄、莖桿、根、莢果壁及種子等六部位，置於送風乾燥箱以 80°C 烘乾 48 小時，稱取乾重後以 Willey mill經40目 (mesh) 篩網磨粉，而種子係以 Phillips HR-2170 磨粉機磨成粉狀；磨粉後之樣品盛於PE塑膠瓶，再以80°C 烘乾24小時後，以內、外蓋封口，置於塑膠袋內密封，供各項營養分析之用。

非構造性碳水化合物 (TNC) 仿 Smith[20] 法分析；係秤取適量樣品，以 0.5% takadiastase ("Clarase 40,000", Miles Laboratories Inc. U. S. A.)於40°C水解44小時，再 以Shaeffer-Somogyi copperiodometric titration method定量，本法曾經預備試驗以標準樣品對大豆樣品進行分析，證實確具精確性。

N素係以Semi-micro Kjeldahl方法測定。

上述二項化學測定均以每一重複爲一樣品，6重複合計爲6個樣品，每一樣品均分析兩次。

結　　果

生育期間葉片TNC濃度變化趨勢呈期作性差異(圖 1A)，同一期作之二品種大致有相同的變化模式；夏作二品種TNC先由 V3 期的高濃度(高雄3號爲11.6%，十石爲15.1%)下降至 V 5 期的 3 %左右，當植株進入生殖生長時TNC濃度迅速升高，二品種分別在 R1 及R4 達到全生育期最高濃度(高雄3號爲15.1%，十石爲 17.3%)，而後便逐漸下降。春作高雄3號與十石二品種除 V3 期外，其他生育期TNC濃度呈相同變化模式，皆在生殖生長期有二高峰，高雄3 號出現在 R1 及 R4 期，其濃度分別爲13.8%與12.1%，自 R4 期後TNC濃度迅速下降，十石品種二高峰在 R1 期(20.5%)及 R5 期 (20.5%)，均較高雄3號高出甚多。繼由圖知生殖生長期，尤其自種子發育開始 (R4 期後)，大豆葉片TNC濃度迅速下降，春作下降較夏作更早。比較二期作葉片在全生育期最高 TNC濃度與成熟時葉片TNC濃度之差異發現，春作高雄3號由 R4 期的12.1%降至 R8 期的 2.7%，下降幅度爲9.4%，而十石由R1 期之 20.5% 降至 R8 期的 2.7%，降幅爲 17.8%；夏作高雄3號及十石之降幅分別爲 7.2% (11.2%～4.7%)及 7.9% (17.3%～9.4%)，春作葉片TNC濃度下降幅度遠較夏作大。

葉柄TNC濃度變化如圖1B，春作二品種之濃度自初期迅速上升，高雄3號及十石分別於 R4 與R5 達最高濃度，各爲 21.8%及 35.4%，而後迅速下降至 3%左右，二品種變化趨勢幾近相同。夏作葉柄TNC濃度較低，皆在 13% 以下，且隨生育期呈下降趨勢。由最高濃度與收穫期最低濃度比較發現，高雄3號春作葉柄TNC濃度之下降幅度爲 18.7% (21.8%～3.1%)，而夏作僅有 7.0%；十石品種春作之降幅爲32.5% (35.4%～2.9%)，而夏作僅6.1%，差距更大。

由圖1C得知春作二品種莖桿TNC濃度之變化趨勢相同，由 V3 期之低濃度逐漸上升，高雄3號於R4 期，十石於 R5 期達最高濃度依次爲 13.2%及 18.1%，而後迅速下降，夏作二品種之變化趨勢並不一致，高雄3號於 R1 期達最高濃度 11.0%，R1期以後除R5期略有回升外，均呈逐漸下降趨勢；十石

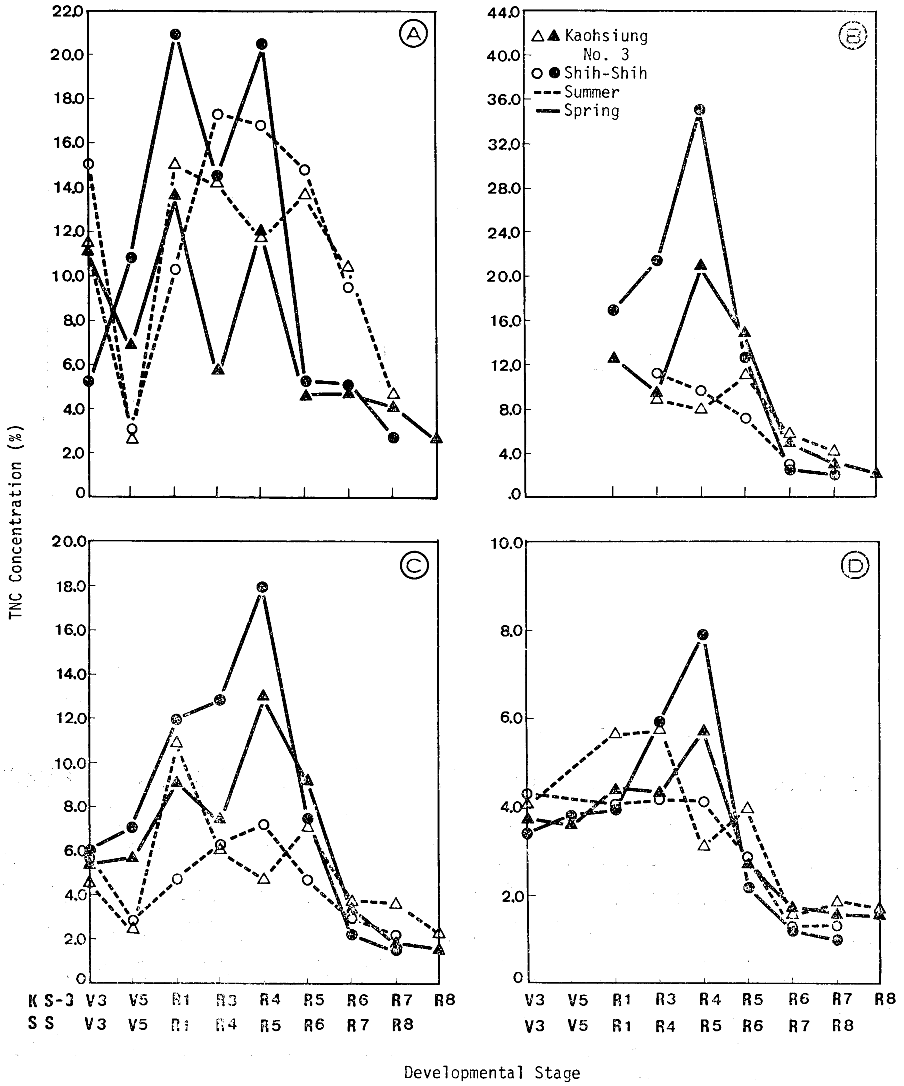

Fig. 1. Changes of TNC concentration of (A) leaf blade, (B) petiole, (C) stem and (D) root of soybean plants at successive developmental stages in the summer (1981) and spring (1982) crop seasons.

品種莖桿TNC濃度自 V5 期逐漸升高，於R5 期達最高濃度（7.2%），然後逐漸下降。比較期作差異發現春作TNC 濃度較高，至成熟時下降迅速，濃度反較夏作爲低；高雄3號春作之降幅爲 11.3%，而夏作降幅僅有 4.8%；十石品種春作下降幅度爲 16.3%，亦高於夏作的 5.0%。

根部TNC濃度之變化期作間亦相類似(圖1D)，春作TNC 濃度逐漸上升，高雄3號和十石分別於 R4 及 R5期達最高濃度(5.7% 及7.9%)，然後迅速下降。夏作十石品種在 R5 期以前均維持於 4% 左右，而後下降；而高雄3號之濃度先逐漸上升於 R3 達最大值5.7%，R3期後亦呈現下降趨勢。

由圖2A得知莢果壁 TNC 濃度皆自初期高濃度逐漸下降，至成熟期略有回升現象。二品種夏作濃度均較春作高，與上述營養器官葉片、葉柄、莖桿及根等之結果截然不同。

種子TNC濃度之變化，期作間或品種間並無一致趨勢（圖2B），但略有自種子最初形成時之較高濃度降至收穫時之低濃度之現象，成熟種子內約含有10—12%的TNC。

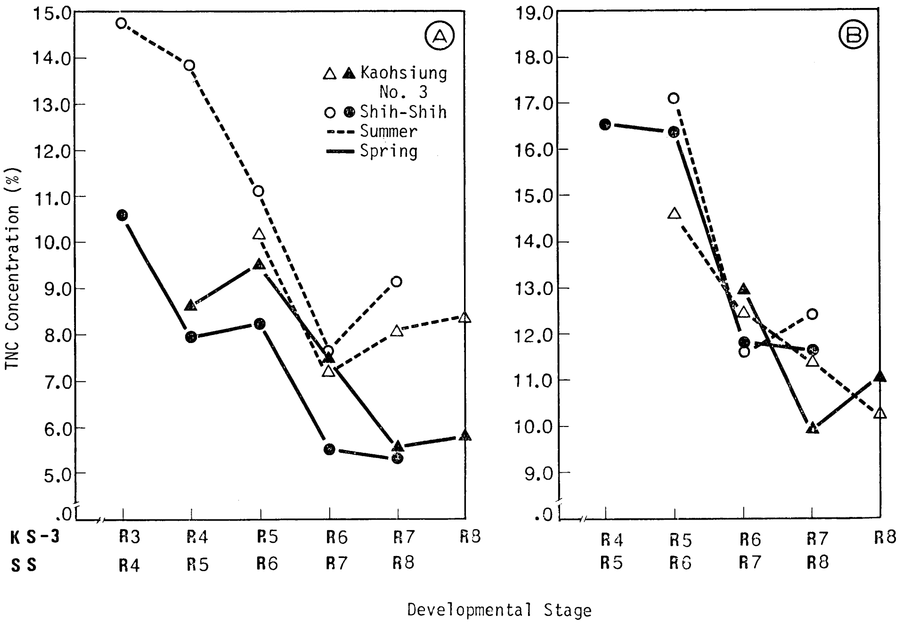

Fig. 2. Changes of TNC concentration of (A) pod wall and (B) seed of soybean plants at successive reproductive growth stages in the summer (1981) and spring (1982) crop seasons.

大豆營養器官中以葉片的 N素濃度最高，在生育各期呈近似起伏的變化（圖3A），春作二品種的變化趨勢較爲一致，皆在 V3期具有全生育期最高的N濃度(4.6—5.2%) 隨後下降，R1 時均低於4%，但豆莢發育期（R3-R4）又行回升，而後隨種子充實而濃度下降，尤以高雄3號的表現較明顯；對脫落前之春作大豆葉片進行分析，發現高雄3號N濃度爲 3.6%，十石爲3.7%。夏作二品種葉片皆於 V5 期有最高N濃度，十石爲4.6%，高雄爲4.5%，而後二品種N濃度除高雄3號於 R4 期略有回升外皆隨種子充實而呈持續下降，成熟時之葉片N濃度均低於2.5%。比較二期作葉片之N濃度，春作遠較夏作爲高，其中又以老化即將脫落的葉片差異最大。

葉柄N素濃度的變化期作間呈明顯差異（圖3B），春作大豆在生殖生長初期，即高雄3號於 R3期，十石於 R4 期有最高N濃度（1.25—0.99%），而後下降，種子開始充實時又略爲上升，而後又逐漸下降。夏作二品種葉柄N濃度皆在 R5 期達最高濃度（1.5—1.7%），而於種子充實期直線下降。無論春、夏作，二品種成熟期葉柄N濃度均低於0.75%。

莖桿N素濃度在 V3 期春作遠高於夏作(圖 3C)，於 R1 前呈下降趨勢，而後濃度逐漸升高，夏作高雄3號於 R4 達最高濃度 1.7%，十石於 R5 亦達最高濃度 1.6%；春作十石品種莖桿N濃度自 R4期便逐漸下降，高雄3號略晚自 R5始呈下降現象，但下降較爲迅速。成熟時莖桿N素濃度皆在0.5%左右，二期作中以夏作略高。

根部N濃度在同一期作有相同的變化趨勢（圖3D）；春作高雄3號在 R3 前，十石於 R6 前之根部N素濃度均較夏作高，且在全生育期內呈持續的下降。夏作二品種 N濃度變化與春作相反，於種子充實前（V3-R5）呈緩慢上升，於R5達最高濃度（1.5%），而後逐漸下降。二期作各品種成熟期根部N濃度皆低於1%，且以春作較低。

自豆莢形成後，莢果壁N素濃度即持續下降（圖4A），夏作高雄3號自 3.5%降至 0.6%，降幅爲2.9%，十石自3.6%下降至0.6%降幅爲3.0%；春作高雄3號降幅爲 2.7%（3.5—0.8%）而十石爲3.7%（4.2—0.5%）。

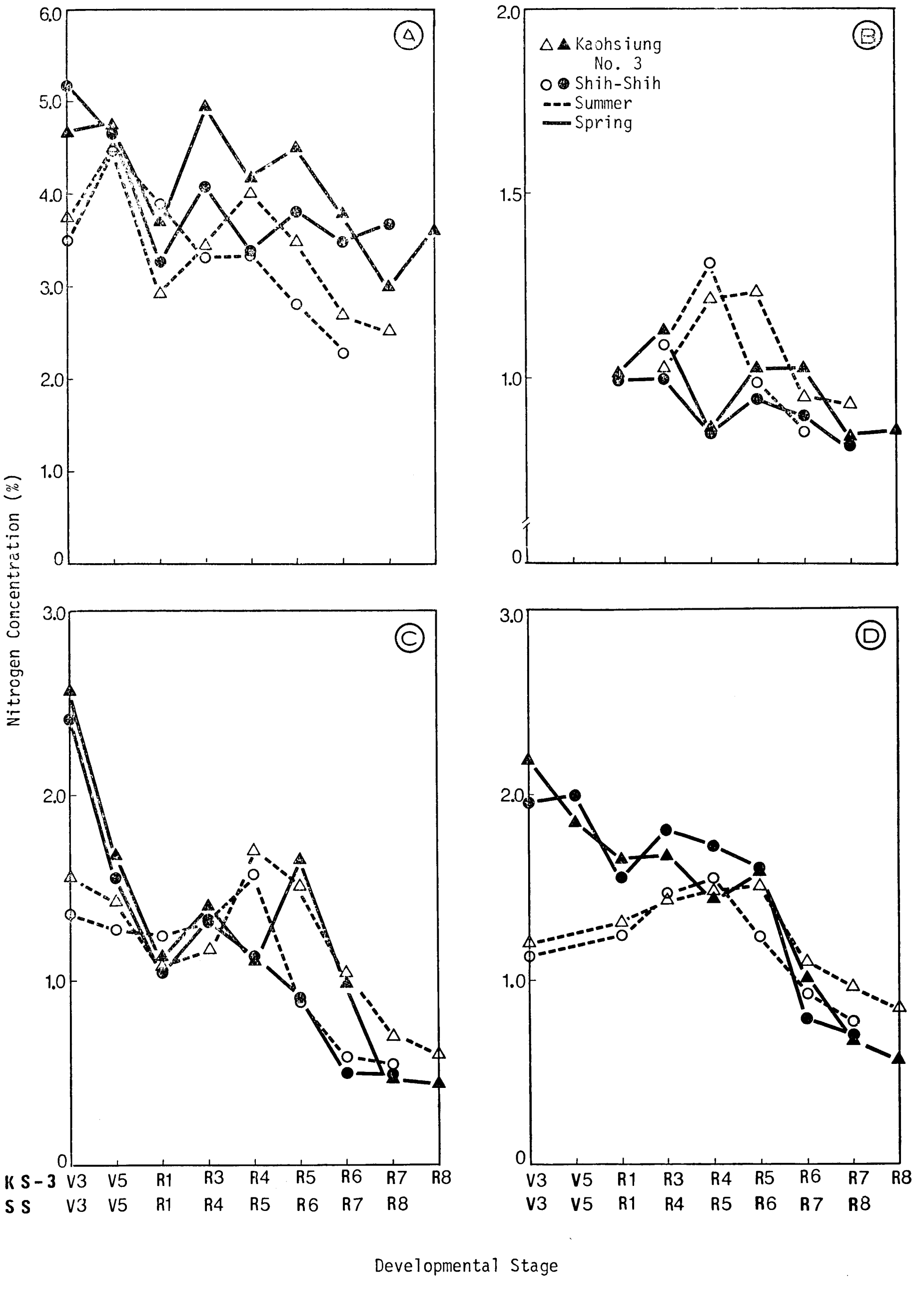

Fig. 3. Changes of N concentration of (A) leaf blade, (B) petiole, (C) stem and (D) root of soybean plants at successive developmental stages in the summer (1981) and spring (1982) crop seasons.

種子爲全株含N濃度最高之部位（5.5—6.8%），種子發育過程 N濃度並無一致的變化趨勢（圖4B），但同一品種在不同期作有相同趨勢，二期作中以春作種子N素濃度較高。

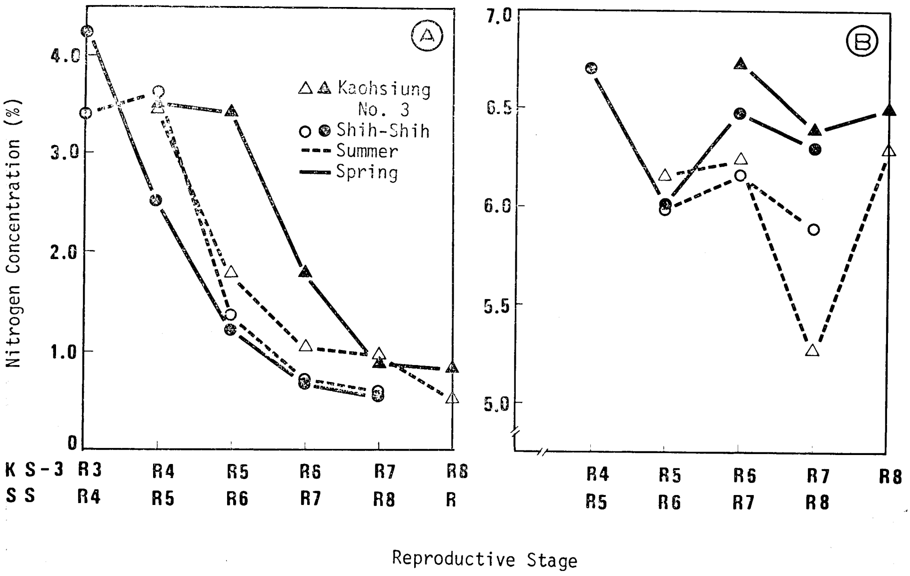

Fig. 4. Changes of N concentration of (A) pod wall and (B) seed of soybean plants at successive reproductive growth stages in the summer (1981) and spring (1982) crop seasons.

討　論

大豆葉片TNC濃度的變化，除春作十石品種外，皆自生育初期 V3 期之較高濃度 (11—15%) 降至 V5 期之 3～7 %，而後又於 R1 期上升至10～15%，此一趨勢與 Huang *et al.*[10] 之結果相似。二品種自種子充實期 (R5) 後，葉片TNC濃度均明顯下降，此與Egli *et al.*[9] 之試驗有相同結果，且降低幅度皆以春作較高，可能是TNC自葉片再轉移至種子所致，Stephenson and Wilson[22] 亦認爲大豆在生長後期，TNC 可直接由葉片轉移至莢果，顯示葉片爲種子所需 TNC 的一項供源。此外 Dunphy and Hanway[7] 更指出種子充實期葉片中TNC能否轉移至莢果爲決定產量的重要因子。春作降幅大，推測是因爲春作葉片老化，脫落較夏作爲早[1]， 導致光合成能力降低，加之春作之溫度隨生育期而升高促使呼吸及消耗增加。

TNC 濃度降低幅度的大小可能無法用以說明或比較春、夏作大豆葉片供源能力的大小，因爲春作濃度降幅雖大，但種子產量偏低，其老化即將脫落的葉片 TNC 濃度已低至 3 %以下，但N素濃度却高達3.5左右，此顯示葉片N素的再轉移無法順利進行，葉片內 TNC濃度大幅下降可能是受老化的直接影響。

生殖生長初期葉柄與莖桿的TNC濃度均以春作爲高，而後期之下降亦以春作較爲明顯，Streeter and Jeffers[24] 指出葉柄與莖桿具有暫時貯存 TNC，而於種子充實期間再行轉移的功能。由於春作葉柄及莖桿有較大乾物累積[1]，此顯示春作大豆葉柄及莖桿可以提供種子較多量的再轉移 TNC；然而Dunphy and Hanway[7] 指出種子充實期葉柄與莖桿TNC濃度的顯著下降可能是光合成物質生產不足，而成爲產量的限制因子；因此，莖桿與葉柄 TNC 濃度於種子充實期大幅下降雖可以提供種子充實之需，然而 TNC 濃度若下降太早、太迅速或下降至太低的水準，可能導致植株生理活性衰退，限制大豆種子後期充實；惟此一莖桿或葉柄所應維持的臨界濃度爲何，仍有待進一步研究。

根部TNC濃度的變化趨勢與葉柄及莖桿相近，R5期以後亦大幅下降，除表示此一期間種子TNC可能自根部轉移而來[12]之外，種子的積儲需求 (sink demand) 最大，限制葉片生產的 TNC 轉移

至根部，Stephenson and Wilson[22] 亦曾證明種子充實階段，植株營養器官轉移至根部的碳水化合物之量極少。

莢果壁在豆莢最初形成時含有高濃度的 TNC，而於種子迅速充實期（R5-R6）大幅下降，顯示莢果壁亦具有暫時貯存TNC而再轉移至種子的功能，與Crookston *et al.*[6] 及 Thorne[26]之試驗結果相同。種子TNC濃度由初期（R5）的高濃度，隨著種子的成熟而逐漸下降，可能原因爲隨著種子成熟，大量TNC被用以做爲合成種子蛋白質的碳架（carbon skeleton），以及合成過程的能量消耗。

比較期作間各部位 TNC 濃度變化發現，春作大豆營養器官於種子迅速充實期開始前均有較高的TNC濃度，而後大幅下降，且成熟時各部位之 TNC濃度反較夏作爲低，顯示春作大豆於種子充實期對營養器官所貯存的 TNC之依賴程度大。此外由於春作葉片提早老化，脫落及低日射量[1]之影響而導致現階段光合生產不足，TNC供應成爲產量的限制因子之一。夏作各部位 TNC濃度於種子充實期下降幅度較小，且成熟期仍有較高的TNC濃度，可能其 TNC供需平衡情形較春作爲佳。再就各部位TNC變化模式而言期作之變化較品種之變化更爲一致，顯示TNC濃度變化受環境因子的影響較大。

春作葉片 N濃度較夏作高，且種子充實期濃度下降幅度較夏作小，即將脫落的葉片內仍有極高的N濃度（3.6%以上），而夏作亦在2.3%以上，雖與Huang *et al.*[11] 在臺中地區之試驗結果相符，但均遠較Streeter[23], Boon-Long[3] 及Zeiher *et al.*[29] 之結果（0.9—1.1%）高出2至3倍，是否因爲本省氣候、環境或其他因子影響使得葉片中的N素無法向外轉移，另外 N素與產量的關係如何，均爲值得探討的問題。春作大豆在生育後期葉片變黃，提早脫落，但仍有極高的N素濃度，顯然此一期間之 N 素濃度不可做爲葉片生理活性之指標，本試驗雖未分析N素之組成（composition），但推測老化葉片蛋白質含量可能較低，由於葉片老化的結果，促使N素轉移能力降低，無法充份供應種子發育之需，再依據Sinclair and de Wit[19] 關於種子充實期氮素需要量（nitrogen requirement for seed development）之假說，N素應有可能對產量造成重大影響。

莖桿與葉柄N素濃度於種子充實期均有明顯下降，顯示營養器官 N素有再轉移至種子的現象，與Sinclair and de Wit[19], Egli *et al.*[8] 及Zeiher *et al.*[29] 之結果相符。其中 Egli *et al.*[8] 指出通常大豆營養器官氮素的再轉移對種子N素含量之貢獻約爲20—24%，然而當豆莢充實期N素缺乏時，此值更可提高至60%。

莢果壁N素濃度隨種子之充實而大幅降低，Crookston *et al*[6], Quebedeaux and Cholbet[16] 及Thorne[26] 認爲莢果壁爲種子N素的主要來源之一。再由試驗結果發現種子 N素濃度之變化頗不一致，推測可能由於全株所有種子成熟程度並不一致及取樣時間間隔太長所致，本研究室未發表之報告顯示，對發育中之種子進行密集取樣分析，N濃度介於5.5—6.0%之間，變化甚小。

綜合大豆全生育各部位TNC及N素濃度之變化，推論春作大豆葉片提早老化可能是因葉片 TNC濃度提早下降至低濃度，而降低其生理活性，並導致大量N素無法轉移。期作間 TNC及 N素濃度之變化呈明顯差異，顯示受環境及氣象因子影響頗大，可爲大豆生長易受環境因子影響[2] 之另一證據。一般而言，營養器官內 TNC及N素濃度以春作較夏作高，尤以種子充實期（R5）前更明顯，因此春作植株營養狀況似乎較夏作良好，然而夏作大豆全乾物質及種子生產量却遠較春作高，可見單就植株各部位 TNC 或N素濃度之高低並無法完滿解釋期作間乾物質生產以及產量之差異，可能尚受氣象因子，營養要素之利用或分配效率及其他未知生理原因之影響。

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Accumulation and Distribution of Nutrients in Soybeans

I. Changes of TNC and N Concentrations during Plant Development[1]

C. S. Wang, M. L. Wei and D. J. Liu

Summary

Two soybean cultivars, Kaohsiung No . 3 (KS-3) and Shih-Shih (SS), were grown in the summer crop of 1981 and spring crop of 1982 at the experimental farm of Taiwan Agricultural Research Institute. Samples were taken at stages of soybean development. Concentrations of total nonstructural carbohydrates (TNC) and nitrogen (N) were determined on different plant parts including leaf blade, petiole, stem, root, pod wall and seed. TNC concentrations in the vegetative organs were very high and the decreases during seed-filling were also extremely prominent in the spring crop. In view of the lower TNC concentration in the senescing leaf blades and lower grain yield of the spring crop, insufficient supply of photosynthetic assimilates to the seeds was proposed as a result of early leaf senescence. Vegetative organs of soybeans grown in the summer crop had lower N concentrations than those grown in the spring crop. The decreases of N concentration in vegetative organs were apparent during seed-filling period, indicating the redistribution of N from vegetative organs to the seeds. Analysis of leaf blades sampled just before abscission showed N concentration of 2.5% in the summer and as high as 3.6% in the spring crop. The high N concentration in the senesced leaf blades indicated the uneffectiveness of retranslocating N to the developing seeds and the unavailability of N to the maintenance of physiological activities of the leaf blades. Changes of TNC and N concentrations in the two cultivars were similar within crop but were different between crop seasons, suggesting the influences of environmental factors were prominent.

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Seeded and Seedless Fruits Growth of "Sah Keng" Litchi[1]

Chung-ruey Yen[2]

Abstract : The growth of seeded and seedless fruits of 'Sah Keng' variety litchi was studied. The seed grew rapidly in the early stage, the normal and aborted seeds could not be macroscopically distinguished untill about 30 days after full bloom. The volume and weight of normal seed increased continually and attended full size about 50 days after full bloom, however the aborted seed grew slowly and ceased about 40 days after full bloom. The growth of volume of seeded fruit, expressed as three components : length, diameter and thickness, was larger than seedless fruit. Increase in fruit length mainly occurred at early stage while that in diameter and thickness mainly occurred at later stage. Fruit weight increased rapidly in the later stage due to the growth of aril. The weight of seeded fruit was heavier than seedless fruit through growth period, but the aril weight between seeded and seedless fruit were not significantly different. It suggested that the seed size might be less important on the growth of aril in litchi. The total soluble solids in fruit increased continually and reached the maximum at maturity. The total soluble solids of seeded fruit was higher than seedless fruit, but not significantly.

Seedless fruits occur frequently in litchi. The size and weight of seedless fruits are smaller than seeded fruits, however, the aril ratio and eating quality, two important characters in litchi, are higher than seeded fruits[13]. The percentage of seedless fruits varies with different varieties, management, locations and years[5,13]. Variety is the most important factor. The 'Groff' variety was reported with 90% of seedless fruit in comparison with 0% in 'Hak Ip', 'Hon Pi' and 'Kaushiang Early' varieties[12,13]. The percentage of seedless fruits of famous seedles varieties are generally between 30--60% in Taiwan[5,13]. One seedling with seedless fruits as high as 99% was found in Nantou recently, however, the fruit size was smaller (about 17g) than 'Hak Ip' and 'Sah Keng' varieties. The percentage of seedless fruits is also affeceted by pollination behavior. In open pollination, none of seedless fruit was found in 'Hak Ip' variety, but in bagging and without-pollination treatment, 100% of seedless fruits could be obtained though the fruit-setting was seriously reduced[7].

The development of litchi fruit showed single sigmoid curve. The embryo develops

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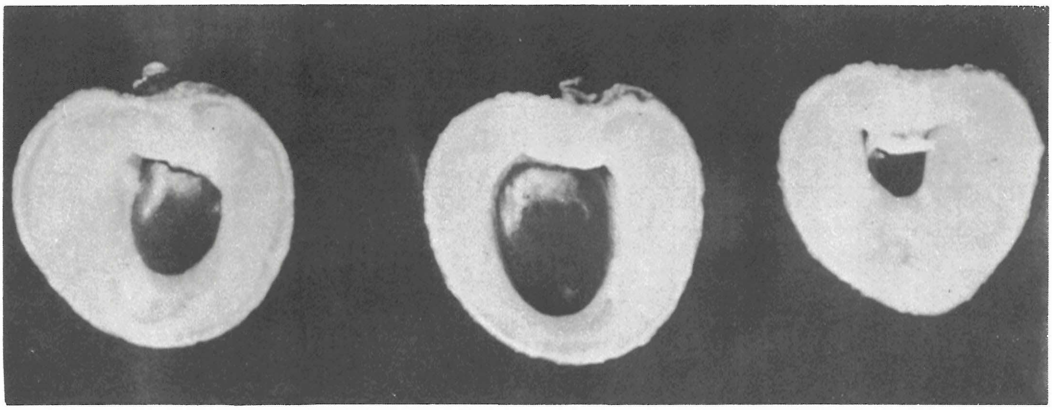

Fig. 1. The longitudinal section of matured seedless fruit (right) and seeded fruit (middle) of "Sah Keng" variety litchi at 80 days after bloom. In the left was a intermediate type which was considered as a seeded fruit.

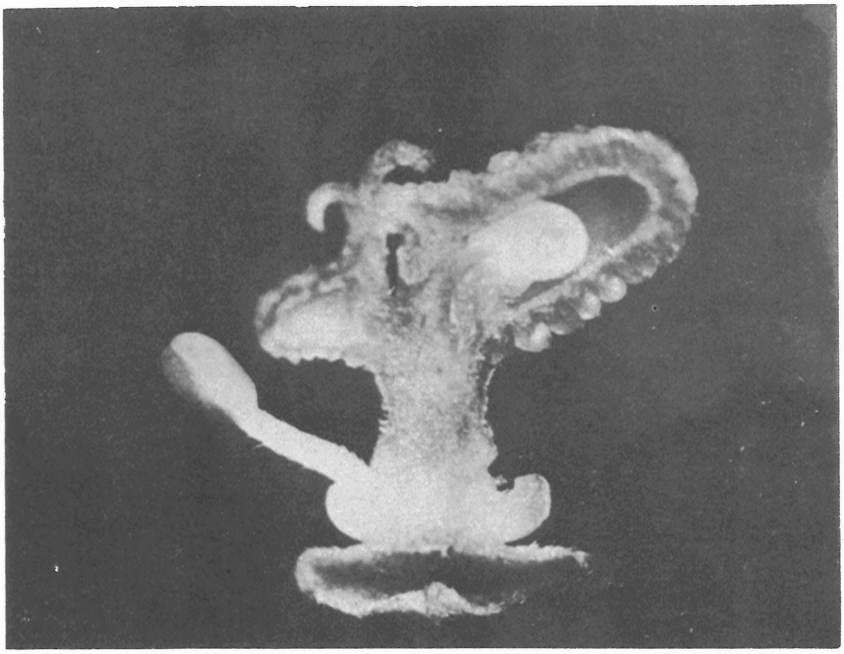

Fig. 2. A longitudinal section of "Sah Keng" variety litchi fruitlet with two loculi at 10 days after bloom. One loculus (at right side) began to grow as a fruit, the growth of other loculus (at left side) was ceased.

primarily in the early stage and the aril grows drastically in the later stage [8,9]. There is few report on the comparison of the differences in various growth components between seeded and seedless fruits. The purpose of this study is to investigate the development of seeded and seedless fruit in 'Sah Keng' variety.

MATERIAL AND METHODS

'Sah Keng' variety of litchi is suitable for this study for its similar number of seeded and seedless fruits [6,13]. In previous experiment, it appeared that the variation among tree was larger than within tree, samples were taken from ten trees to reduce the errors [13]. Fruits were collected from ten years old 'Sah Keng' variety grown in Chuchi, Chiayi. Ten fruits were sampled randomly from each tree at ten days interval from full bloom to maturity. The growth of fruit was determined on the basis of length, diameter, thickness and weight [3]. The length, diameter and thickness of fruit were measured with caliper, the total soluble solids was determined with hand refractameter. After fruit characters were measured, the seed was longistudinally cut to identify whether it was a normal or aborted (Fig. 1).

RESULTS AND DISCUSSION

After fertilization the fruit began to grow rapidly. The ovary has generally two loculi but usually only one loculus grew to form a fruit (Fig. 2). The growth of seed and fruit are expressed as cumulative weight and volume. The growth curve of litchi fruit was sigmoid. The volume of fruit showed a stable increase through the growth period. In contrast, the increase of fruit weight was faster during later stage. The growth pattern expressed either as volume or as weight, was significantly different in seeded and seedless fruits. The changes of percentage of fruit components in whole fruit on weight basis was shown (Fig. 3). The weight of seeded fruit was significantly higher than that of seedless one from 40 days bloom through maturity (Fig. 4). The peel

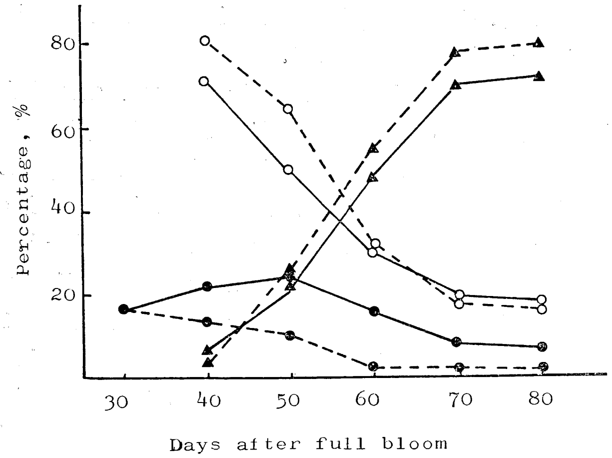

Fig. 3. Chages of percentage of seed (●), peel (○), and aril (▲) in whole fruit on weght basis. The differences between seeded (—) and seedless (···) litchi fruits were appeared.

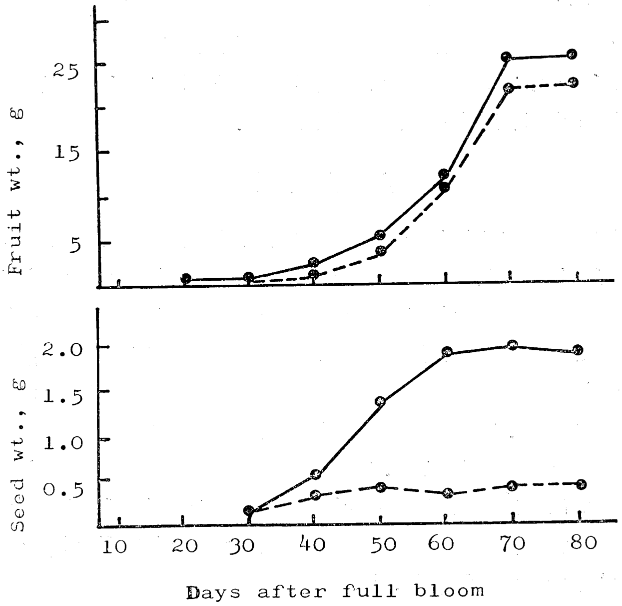

Fig. 4. Changes of fruit weight and seed weight of seeded (—) and seedless (···) fruits in 'Sah Keng' variety litchi.

and seed increased distinctly in the early stage, then slowed down from 60 days after full bloom. In early period, peel and seed were two main components of fruit (Fig. 3, 4, 5). In early stage, the aril could hardly be observed macroscopically but increased drastically during 50 to 70 days after full bloom. The percentage of aril in seedless fruit was significantly higher than seeded fruit (Fig. 3). In most fruit species, seed is a strong sink and via synthesis of growth substances, influence the growth of other fruit componets specially the edible pericarp. Aborted seed usually resulted in smaller and unmarketable seedless fruit [1], however, it appeared difference in litchi. The aril weight, despite of the difference of seed size, were not significantly differant in seeded and seedless litchi fruits (Fig. 5). It indicated that the influence of seed size on aril growth might not be so important as in other fruit [1].

The total soluble solids of fruit incresed gradually and attended the highest value at maturity (Fig. 5). Fang and Huang [4], and Lin and Chiang [10] also reported that the increase of total soluble solids was accompanied with the progress of maturity and reached the maximum in fully matured fruit. The fruits harvested at 7 'fen' maturity or 70% fruit peel turning red color had the longest storage life [10]. It seemed that the fruits of 'Sah Keng' variety harvested about 75 days after full bloom when the fruit volume, weight and total soluble solids was closely approched to that at maturity might be suitable for long distance transport. The total soluble solids in seeded fruit were higher than in seedless fruit, but it was not significant. This result confirmed previous report [13]. Huang considered that the flavor of seedless fruit was better than seeded fruit [5], but Mustard *et al* reported that quality of seedless fruit was inferior to seeded fruit [11]. Different varieties may explain the discrepant results.

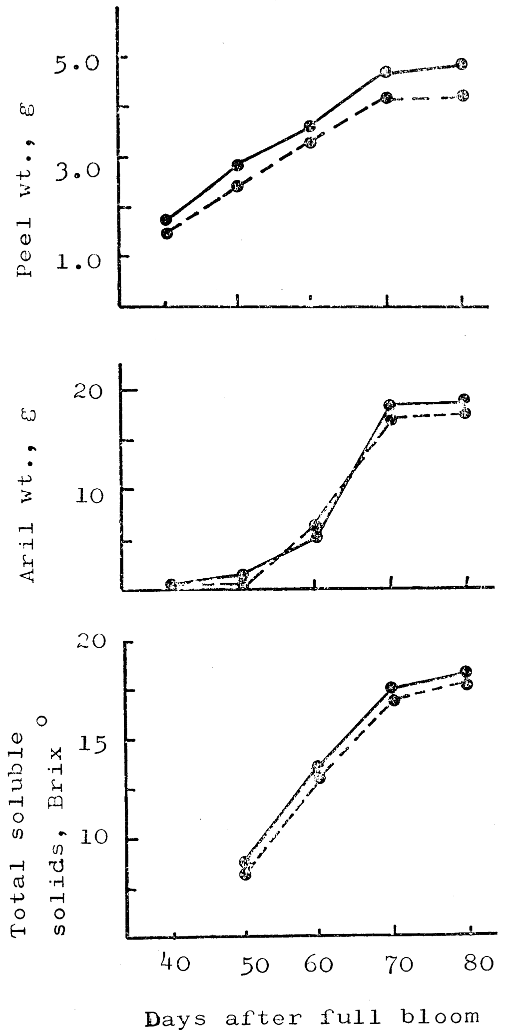

Fig. 5. Changes of peel weight, aril weight, and total soluble solids of seeded (—) and seedless (···) fruits in 'Sah Keng' variety litchi.

The volume of fruit was separated into three components : length, diameter and thickness. The increase of length was fast during 20 to 50 days after full bloom, while the increse of diameter and thickness was fast during 60 to 70 days after full bloom. The growth patterns of length, diameter and thickness were similar in seeded and seedless fruit (Fig. 6). The difference of fruit length of seeded and seedless fruit was not significant through the whole growth period, but the differences of diameter and thickness of fruit were significant from 40 to 80 days after full bloom. The diameter and thickness of seeded fruit were higher than seedless fruit. This confirmed previous report that there was a high correlation between seed size and fruit diameter, but the correlation between seed size and fruit length was low and not significant. As compare the time of seed growth and increase of diameter and thickness, it seemed that seed might play a role in growth of fruit diameter and thickness, which develop faster during later stage, thus, the diameter and thickness of seedless fruit were smaller might be due to seed aborted during early stage.

The increase of weight and volume of normal and aborted seeds showed significantly different from 30 days after full bloom through maturity. The increase of seed volume was fast at early stage, then ceased and the color of seed coat turned from green to brown about 50 days after full bloom (Fig. 6, 7). The growth pattern of volume components : length, diameter and thickness were similar in both normal and aborted seeds, but the volume of aborted seed was smaller and the growth ceased earlier than normal seed (Fig. 6). The increase of seed weight in normal and aborted seed showed significant difference. The normal seed grew continually and the inner parts was filled with embryo, however, the increase of weight of aborted seed ceased about 40 days after full bloom. the weight was never beyond 0.5 gram (Fig. 4) and a brown residual of ovule was observed in the cavity at 30 days after bloom (Fig. 8). Chang[2]

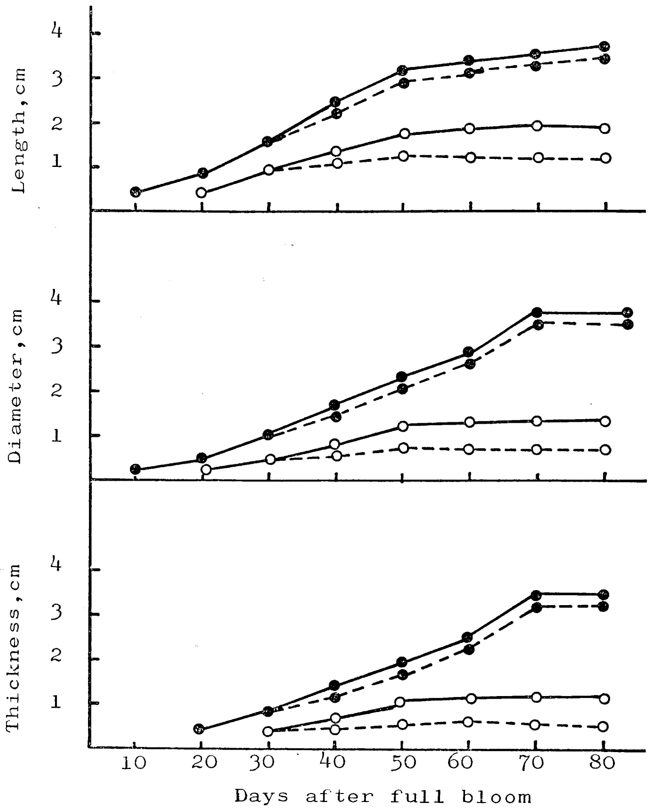

Fig. 6. Changes of volume components of fruit (●) and seed (○) between seeded (···) and seedless (···) fruits in 'Sah Keng' variety litchi.

and Mustard *et al*[11] reported that there was a large number of fruit drops as a result of embryo abortion from 2 weeks to 4 weeks after bloom. In this study the normal and aborted seed could not be distinguished untill 30 days after full bloom. It was evident that there was a critical period of fruit-setting from 10 to 30 days after full bloom. After this period the setted fruits grew rapidly despite that it was a normal or aborted seed inside.

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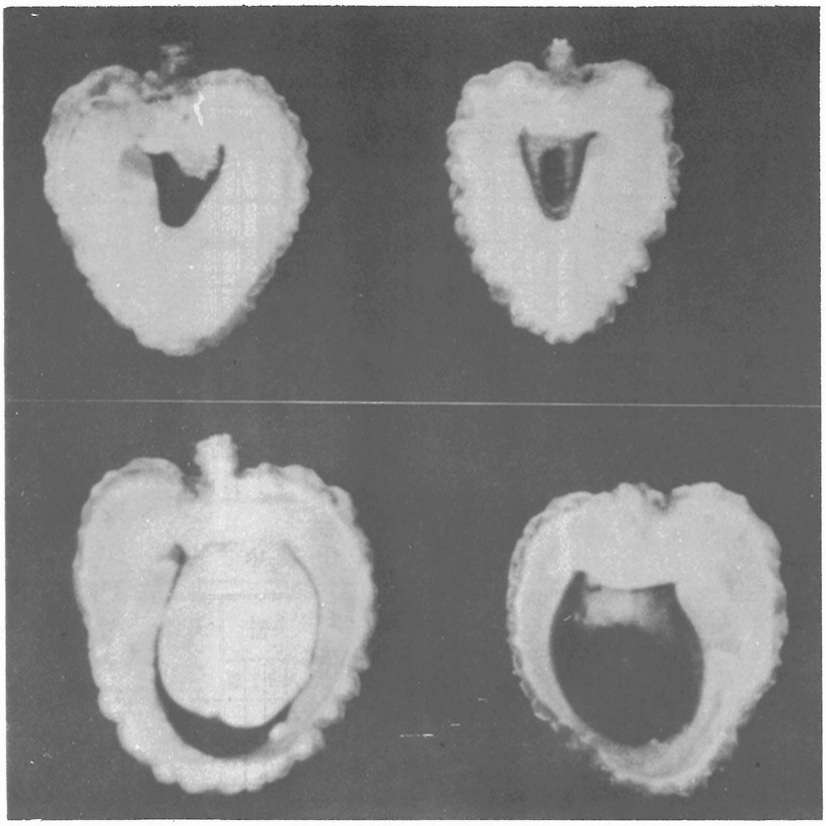

Fig. 7. The normal seeds (lower row) and aborted seeds (upper row) of "Sah Keng" variety litchi had approached full size 60 days after full bloom, but the growth of fruit volume and aril were not yet completed.

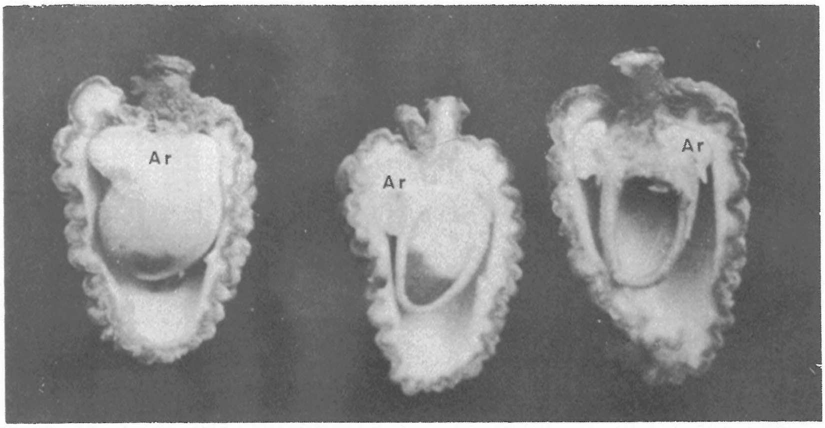

Fig. 8. The normal and aborted seeds could only be distinguished untill 30 days after full bloom, the cavity of normal seed was filled with cotyledons (middle) , but in aborted seed, a brown residual of ovule was observed in the cavity (right) , it was also shown that the aril (Ar) began to grow in both normal and aborted seeds (left) .

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沙坑種荔枝正常果及焦核果之生長[1]

顏 昌 瑞[2]

摘 要

研究荔枝沙坑種正常果及焦核果各構成部份之生長顯示種子於初期迅速增大，至花後30天正常及焦核種子發育即有顯著不同，此後正常種子之體積及重量均繼續增加，至花後50天即接近成熟大小，焦核則生長緩慢至40天即停止發育。果實體積以果長、果徑及果厚表示，正常果均大於焦核果，果長於初期增加較速，果徑及果厚在後期增加較速。果重在發育後期因果肉之生長而迅速增加，於發育過程，正常果之果重均顯著大於焦核果，但果肉重之差別則不顯著，顯示種子大小對果肉生長之影響不大。果肉可溶性固形物含量於發育期持續增加，至成熟期達到最高，正常果之可溶性固形物含量高於焦核果，但二者差異不顯著。

1.臺灣省農業試驗所 研究報告第 1166 號。

2.本所嘉義農業試驗分所園藝系助理研究員。臺灣省 嘉義市。

中華農業研究（Jour. Agric. Res. China）33(3)：265～275（1984）

稻田土壤還原電位之檢定及用於水分管理之研究[1]

黃 明 輝[2]

摘要：本研究首先探討本省稻田土壤還原電位(Eh)之分佈及其對水稻生產之影響，進而研究晒田對土壤 Eh 和水稻生產之影響，以尋求合理的水分管理。

（一）一期作時，片岩冲積土及東岸母岩冲積土之稻田較易發生高度還原問題。二期作在晒田前所有土類的土壤 Eh_7（Eh at pH7.0）皆低於 −150mV，指出二期作水稻分蘖盛期之土壤已高度還原。

（二）一期作晒田前之土壤 Eh 和稻穀產量有顯著正相關（r＝0.24*）。二期作晒田後之土壤 Eh 和稻穀產量亦爲顯著正相關（r＝0.34*）。這顯示土壤 Eh 是影響水稻生產的重要因子；並且指出測定時機，一期作在晒田前，二期作在晒田後。

（三）晒田是提高土壤 Eh 的有效方法。水分管理用 W_2 之間歇灌溉方法對二期作水稻生產最有利，此方法比推薦法 W_3 增產稻穀10%。

土壤浸水後，其物理、化學和生物的性質皆起變化，而影響水稻的生長。因爲浸水，使大氣和土壤間的氣體交換減緩，一天之內氧氣幾乎全部消失，造成土壤的還原狀態[11]，依土壤特性，其還原電位（Eh）可降至 0.2～0.3V（Volt）之範圍內，但是表土上面水分及最上面數公分的土壤仍維持 0.3～0.5V[9]。在無分子氧的情況下，還原電位是水田還原程度的最好指標，它可提供土壤中化學和生物變化的訊息[4,8]，並且還原電位低於 200mV 時，測定 Eh 較測定氧氣擴散速率或還原物質濃度爲佳[5]。浸水土壤的 Eh 可分爲四個等級，依次爲高度還原（−300～−100mV）、還原（−100～100mV）、中度還原（100～400mV）和氧化狀態（400～700mV）。

因爲土壤的不均勻，白金電極直接插入土壤測定 Eh 其測値間差異很大，有差至 300mV者[6,7]。若以一支白金電極測定土壤 Eh，其標準偏差爲80～90mV。若用20至40支白金電極測定土壤 Eh 其平均値的標準偏差降爲 10～20mV[2]。影響白金電極測定土壤 Eh 的因子有白金電極前處理、白金絲表面積、白金電極和土壤接觸時間，有機質及氣溫等[1,12]。在白金絲表面積 11.8～24mm^2 和白金電極絕緣部分之直徑 5 或 8 mm 條件下，白金電極與土壤接觸 8 小時可達平衡[1]。若有足够分解性有機質則 Eh 也許會降至 −300mV[12]。

土壤 Eh 愈低，土壤愈還原。低 Eh 有害於發芽、秧苗生長及根系發展[3,10]，但不妨害健全植株的生長[10]。適合水稻生長之 Eh, Ponnamperuma(1978)[10] 主張是土壤溶液 Eh_7（Eh at pH7）

1. 臺灣省農業試驗所 研究報告第1167號。本文承蒙中興大學楊教授策羣、本所農化系林主任家棻和儀器化驗室李任蘭帝指導，助理研究員林先生登鴻和各農改場土肥股同仁全力協助，以及農發會經費補助，特此致謝。

2. 本所農化系助理。臺灣省 臺中縣 霧峰鄉。

10～120mV，然而曾氏（1981）[3] 卻主張是土壤 Eh_7（晒田後）－73～－100mV 二種不同觀點是因爲土壤還原後，溶液 Eh 高於土壤 Eh 0.3～0.4V。

本省稻田之土壤母質大部是冲積土，缺乏良好構造，加上浸水下犂田所形成的泥漿，阻塞土壤孔隙，使底土愈來愈密實，故中細質地稻田的滲漏速率偏低。在本省二期作，高溫多雨的氣候下，土壤較易產生還原問題，或將不利於水稻的生產。晒田至 0.2 bar 小區可將土壤 Eh 由浸水時的負值提高至 200mV，而且比浸水區增產稻穀19％[2]。本研究一方面配合土壤肥力能限分類與應用計劃，至全省 80 處水稻氮肥試驗田檢定土壤 Eh 探討本省稻田土壤 Eh 之分佈及其對水稻生產之影響。一方面在本所農場進行水分管理試驗，研究晒田對土壤 Eh 和水稻生產之影響，以尋求適合本省水稻生產之水分管理方法。

材料及方法

試驗一：本省稻田土壤還原電位之檢定及其對水稻生產之影響。

一、檢定地區及土類：

本試驗配合土壤肥力能限分類與應用計畫，至本省各地水稻氮肥試驗田測定土壤還原電位（Eh）、pH 和土溫。民國71年一期作測定80處，高雄區15點、臺南區15點、臺中區20點、桃園區12點、花蓮區 9 點及臺東區 9 點。二期作測定43處，高雄區 6 點、臺南區 7 點、臺中區16點、桃園區 6 點、花蓮區 3 點及臺東區 4 點。全部試驗田土壤按母質來源分七大類，砂頁岩冲積土（SSA）、粘板岩冲積土（SA）、砂頁岩及粘板岩混合冲積土（SSSA）、紅壤（RE, 含紅壤冲積土及黃壤）、東岸母岩冲積土（EMA, 含黑色土）、片岩冲積土（ScA）及臺灣粘土（TCA）。

二、檢定時間：

在水稻分蘖盛期（一期作在插秧後28至38天，二期作在插秧後20至30天，晒田前）以及插秧後70至100天（晒田後）各測定土壤 Eh 一次。

三、測定方法：

（一）白金電極之製造：

用銼刀切割玻璃管（鈉玻璃、內徑 3mm、外徑 5mm）爲 20cm 長，一端在本生燈火焰上加熱，管口縮小至 1mm 時，迅將白金絲（長 1cm、直徑 0.8mm））放入5mm 再加熱使白金絲與玻璃管完全融合，冷却後，從另一端塞入一束細銅絲，再插入銅棒（長 25cm、直徑 2mm），使銅棒經銅絲與白金絲保持良好接觸，端口再用熱縮管加熱密封。

（二）白金電極之檢驗：

白金電極插入 Eh 緩衝液中（0.0033M $K_3Fe(CN)_6$、0.0033M$K_4Fe(CN)_6$ 及 0.1M KCl 混合液），測定其電動勢（emf），如測值互相間差異 2mV 以上者棄之。

（三）土壤 Eh 之測定：

白金電極直接插入田間土壤中（距離稻叢 5～10cm）或間接插入田間採回之土柱上（直徑 9cm 長 12cm），插入深度約 8cm，待24小時後，以 pH 計測定其電動勢（測定時，參考電極放在田面有水處即可），同時測定土壤 pH 及溫度，再依公式 1 或 2 換算爲 Eh_7。

公式 1：$Eh_7 = emf + 242 + 59(pH-7) - 0.8(T-25)$

公式 2：$Eh_7 = emf + 200 + 59(pH-7) - 1.0(T-25)$

式中 Eh_7 是 pH7 之土壤還原電位（mV）、emf 是電動勢（mV）、pH 是土壤 pH值，T 是土壤的攝氏溫度（°C）、59 是每增加一個 pH 單位所增加的電壓，242 及 0.8是參考電極爲飽和甘汞電極在 25°C 時之電位及溫度係數。200 及 1.0 是參考電極用飽和銀一氯化銀電極在 25°C 時之電位及溫度係數。

每處試驗田測定 3 區（氮推薦區、氮增施區和氮減施區），每小區測20點，計每處測60點土

壤 Eh 值。

試驗二：水分管理對土壤 Eh 及水稻生產之影響

自民國70年二期作至72年一期作，在本所25號水田（土壤 pH5.7，有機質1.6%，坋質粘壤土）利用自製水銀張力計控3種水分管理並配合2種氮肥用量，計6處理，4重複，裂區設計排裂，主區是水分管理，副區是氮肥用量，進行水稻（臺農67號）田間試驗。3種水分管理如下：

W_1：浸水至插秧後20至30日，接著間歇灌漑（即灌漑後等土壤晒至土壤水分張力接近0.2bar 再灌漑）至黃熟期。

W_2：浸水至插秧後40至50日，接著間歇灌漑（同 W_1）。

W_3：浸水至有效分蘗期，然後輪灌（排水稍乾後再灌漑），隨後晒田一次至田面有小裂縫為止，接著幼穗形成期及抽穗開花期保持浸水，其他時間輪灌（農林廳推薦法）。

2種氮肥用量：一期作是120及150 kg/haN 二期作是100及130 kg/haN。P_2O_5 和 K_2O 都各施60 及 90kg/ha。土壤 Eh 測定時間同試驗一，每小區測20點。

統計分析：全省測定之土壤 Eh 值，先求每處60個 Eh 值之平均值及平均值標準偏差，再把平均值換算為 Eh_7 代表該處土壤還原電位。利用此資料和土壤肥力資料（有效性磷、鉀、矽、鋅、有機質、游離鐵及交換性鈣）以及稻穀產量資料（每處以氮推薦區、氮增施區及氮減施區等3小區，4重複，12小區求平均值代表該處產量）列表及畫圖，再以直線及複迴歸分析，找出影響水稻生產之因子以及適合水稻生長之土壤 Eh 值。最後分析水分管理試驗之資料來闡明水分管理對土壤 Eh 和水稻生產之意義。

結果及討論

一、土壤還原電位和土類之關係：

本省主要土類的土壤還原電位分佈及變異，如圖1、2及表1、2。民國71年一期作時，晒田前土壤還原電位，Eh_7 依序為 ScA<EMA, RE<SA<SSSA<SSA<TCA，指出一期作時本省土壤以片岩冲積土最還原，其次為東岸母岩冲積土、紅壤及粘板岩冲積土，而以混合冲積土、砂頁岩冲積

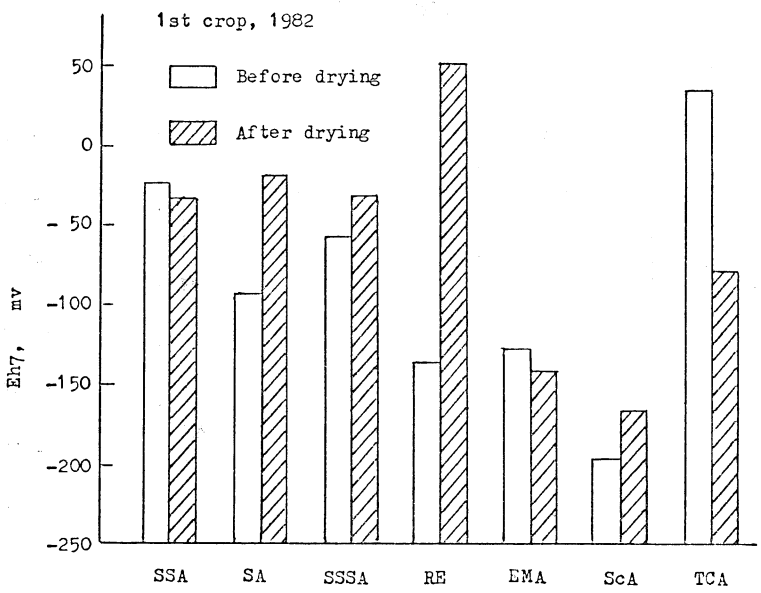

Fig. 1 Comparison of soil redox potential among soil categories

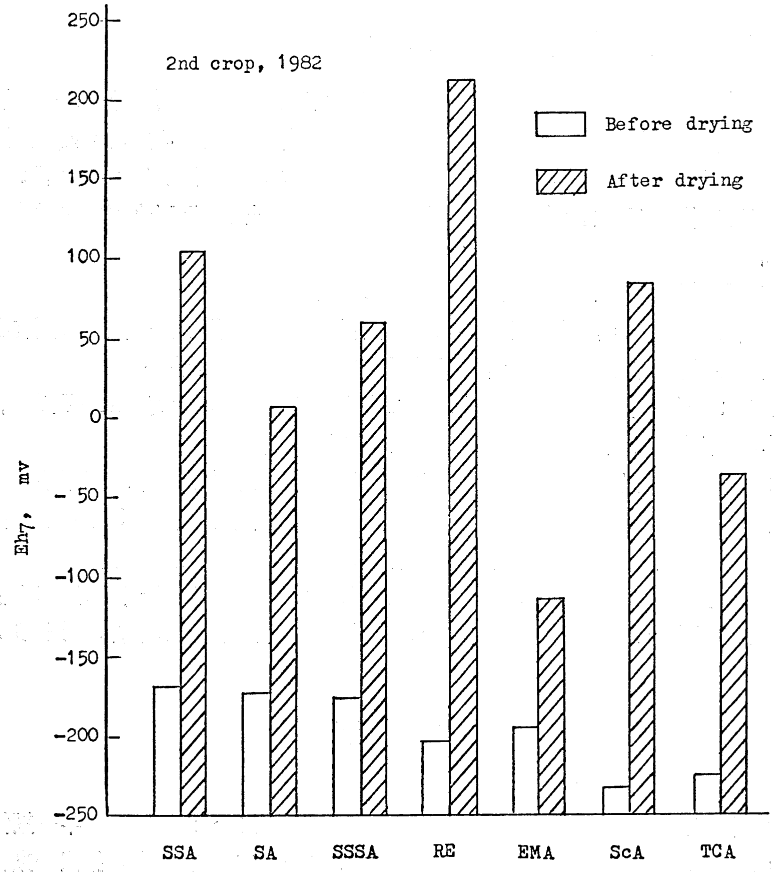

Fig. 2 Comparison of soil redox potential among soil categories

Table 1. Comparison of soil redox potential among soil categories (1st crop, 1982)

Soil categories	n	Eha	Ehb
		mv	mv
SSA	23	− 22±17	− 37±34
SA	22	− 92±16	− 22±25
SSSA	7	− 59±41	− 37±53
RE	8	− 136±14	48±41
EMA	3	− 125±50	− 142±55
ScA	10	− 194± 9	− 164±48
TCA	4	38± 8	− 80±22

* mean value with standard error of mean

* a : before drying. b : after drying

Table 2. Comparison of soil redox potential among soil categories

(2nd crop, 1982)

Soil categories	n	Eha	Ehb
		mv	mv
SSA	12	− 170±19	103± 51
SA	12	− 173±10	8± 41
SSSA	5	− 178±12	59±111
RE	3	− 202±40	207±111
EMA	3	− 195±15	− 114± 37
ScA	5	− 231±11	80± 99
TCA	3	− 225± 5	− 40± 12

* mean value with standard error of mean

* a : before drying. b : after drying

土及臺灣粘土較不還原。晒田後土壤 Eh_7 之順序為 ScA<EMA<TCA<SSA, SSSA, SA<RE，仍以 ScA 及 EMA 之 Eh_7 最低（−150 mV），顯示一期作時，片岩及東岸母岩冲積土較易發生過度還原問題，亦即東部地區水田一期作時較易發生土壤過度還原問題。

二期作時，晒田前土壤 Eh_7 無論那一種土類，均低於 −150mV，顯示土壤已經相當還原，必須晒田。晒田後，除了東岸母岩冲積土及臺灣粘土的土壤 Eh_7 仍為負值外，其他土類之土壤 Eh_7 都升為正值，可能是東岸母岩冲積土及臺灣粘土晒田不足或未晒田所致。

無論那一種土類，二期作之土壤還原電位均低於一期作，表示二期作較易產生過度還原問題。又晒田前之土壤 Eh_7 標準偏差低於晒田後者，顯示晒田前土壤 Eh_7 分佈較均勻。

二、土壤還原電位和水稻產量之關係

由土壤還原電位與稻穀產量頻度圖顯示，民國71年一期作時，晒田前土壤 Eh_7 在 −200～−100 mV 之稻穀產量最低，其次為 Eh_7<−200mV 及 −100～0mV，而以 Eh_7>0mV 之稻穀產量較高（圖 3）。相反地，晒田後，却以土壤 Eh_7 在 −200～−100mV 之稻穀產量最高，而以 Eh_7>100 mV 之稻穀產量較低，此頗為矛盾。若從表 3 之相關矩陣，可發現晒田前土壤 Eh_7(Eha) 和稻穀產量有顯著正相關（r＝0.241），而晒田後土壤 Eh_7(Ehb) 却沒有明顯關係，這指出一期作水稻時，晒田前土壤還原電位較能反應水稻生長。此結果大致和曾氏[3]所得結果相符。

二期作時，晒田前土壤 Eh_7 均為負值，0～−100mV, −100～−200mV 及 <−200mV 各佔 5，51 及 44%，即95%土壤 Eh_7 低於 −100mV（圖 4），顯示二期作水稻生長初期土壤已相當還原，但所劃分三個範圍之土壤 Eh_7 的稻穀產量並沒有明顯差異。晒田後，72%之土壤 Eh_7 均上升至 −100mV 以上，而且隨著土壤 Eh_7 回升而使稻穀增產的趨勢極為明朗。又從表 4 發現晒田後土壤 Eh_7(Ehb) 和稻穀產量有顯著正相關（r＝0.344），此顯示二期作水稻時，晒田後土壤 Eh 較能反應水稻之生長。

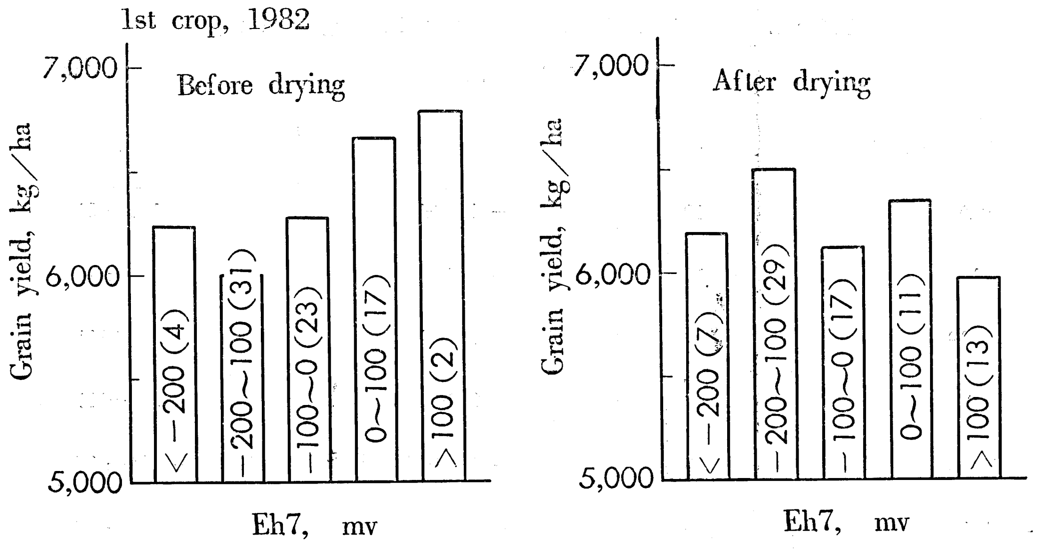

Fig. 3 Effect of soil redox potential on yield of rice.
(Data in each bar indicate the range of Eh_7, while those in ( ) show the number of field trials)

Table 3. Linear correlation coefficients between soil properties and grain yield
(1st crop. 1982. n=77)

Ehb	−0.10								
P	−0.06	−0.02							
K	0.25*	0.11	0.10						
OM	−0.40**	−0.04	−0.29*	0.19					
Fe	0.12	0.24*	−0.32**	0.26*	0.17				
Si	0.14	0.02	−0.27*	0.26*	0.20	0.28*			
Ca	−0.00	0.00	−0.41**	0.07	0.19	−0.10	0.17		
Zn	−0.19	−0.13	−0.03	0.02	0.22*	0.00	0.16	−0.02	
Yield	0.24*	−0.10	−0.06	0.14	−0.03	0.11	0.12	−0.22*	0.17
	Eha	Ehb	P	K	OM	Fe	Si	Ca	Zn

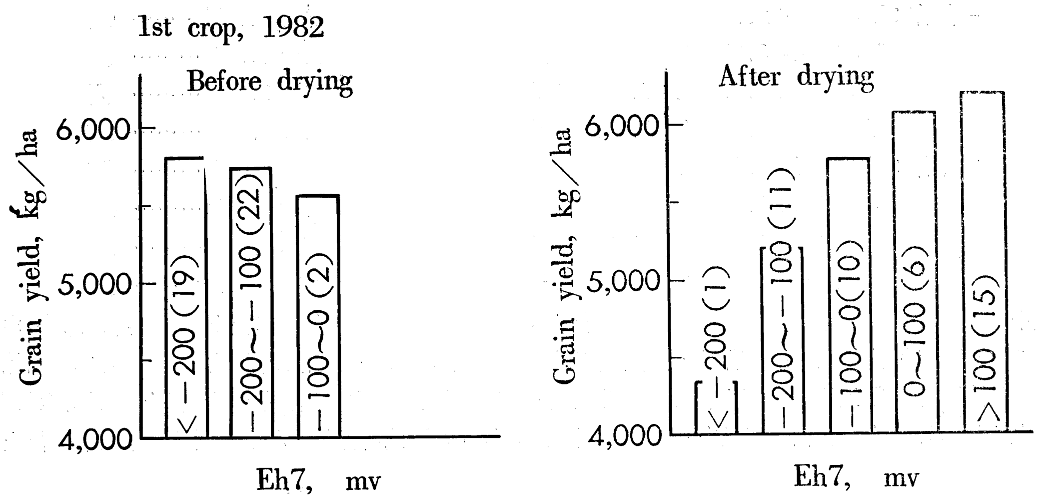

Fig. 4 Effect of soil redox potential on yield of rice.
(Data in each bar indicate the range of Eh_7, while those in ( ) show he number of field trials)

Table 4. Linear correlation coefficients between soil properties and grain yield (2nd crop. 1982. n=43)

Ehb	−0.04								
P	−0.05	−0.01							
K	0.12	0.01	0.12						
OM	0.04	0.03	−0.35*	0.18					
Fe	0.28	0.10	−0.26	0.22	0.20				
Si	0.14	−0.03	−0.37*	0.16	0.20	0.17			
Ca	−0.13	−0.29	−0.29	−0.03	0.13	−0.23	0.02		
Zn	0.00	0.18	0.05	0.02	0.16	−0.06	0.03	0.04	
Yield	0.12	0.34*	−0.13	0.35*	0.13	0.11	0.09	0.02	0.37*
	Eha	Ehb	P	K	OM	Fe	Si	Ca	Zn

最適水稻生長之土壤 Eh_7 究爲何值或範圍，經直線及曲線迴歸分析結果如下：

一期作：$Y=6502+2.68Eha$ $R^2=0.058^*$ ……… (1)

$Y=6254-0.69Ehb$ $R^2=0.009$ ……… (2)

$Y=6488+2.97Eha+0.0024Eha^2$ $R^2=0.059$ ……… (3)

$Y=6223-0.75Ehb+0.0012Ehb^2$ $R^2=0.010$ ……… (4)

二期作：$Y=6184+2.43Eha$ $R^2=0.015$ ……… (5)

$Y=5662+1.83Ehb$ $R^2=0.119^*$ ……… (6)

$Y=4834-15.91Eha-0.056Eha^2$ $R^2=0.046$ ……… (7)

$Y=5948+3.81Ehb-0.011Ehb^2$ $R^2=0.257^{**}$ …… (8)

式中 Y 是稻穀產量 (kg/ha), Eha 是晒田前土壤 Eh_7(mV), Ehb 是晒田後土壤 Eh_7(mV) 。由（1）至（4）式指出，一期作時，雖然晒田前土壤 Eh_7 和稻穀產量有顯著正相關，但是二次曲線未達顯著水準，難以找出最適土壤 Eh_7。然而（5）至（8）式顯示二期作時，晒田後土壤 Eh_7 (pH7 時之土壤還原電位) 和稻穀產量有顯著正相關，而且從（8）式所得相關曲線（圖 5）指出晒田後土

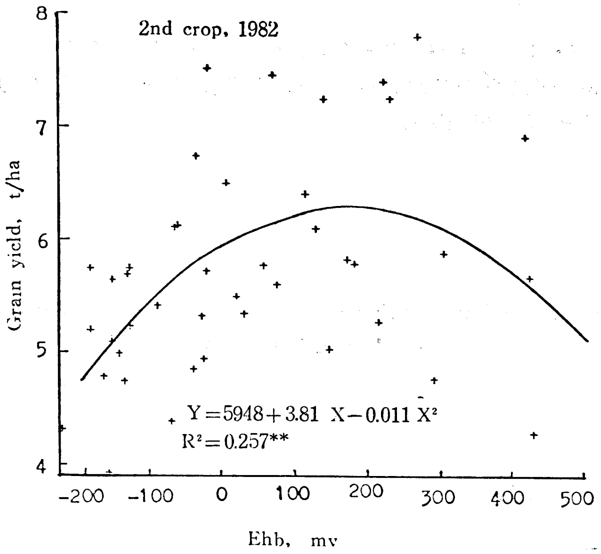

Fig. 5 Rice yield affected by soil redox potential measured after drying.

壤 Eh_7 173mV 時，稻穀產量最高。此和曾氏所得 −73mV 頗有不同，因爲①曾氏[3]結果是一期作，本結果是二期作。②二期作土壤比一期作土壤還原甚多（表 1 、 2）更需要晒田，促使土壤還原電位上升愈多，愈有利於水稻生長。既知土壤還原電位和稻穀產量有密切關係，故欲利用土壤基本性質預估土壤還原電位，以預測那類土壤易發生過度還原問題，提供稻田土壤水分管理之參考。茲將迴歸分析結果略述如下：

一期作：$Eha=4.98-31.3OM$ $R^2=0.16^*$ ……… (9)

$Eha=-24.14-36.33OM+0.287K$ $R^2=0.271^{**}$ ……… (10)

$Eha=1.17-32.79OM+0.248K-10.09SC$ $R^2=0.312^{**}$ ……… (11)

$Eha=-100-34.64OM+0.234K-8.68SC+11.06pH+8.54T$ $R^2=0.346^{**}$ ……… (12)

二期作：$Eha=-158-10.19SC$ $R^2=0.185^{**}$ ……… (13)

$Eha=-212-10.88SC+11.66T$ $R^2=0.303^{**}$ ……… (14)

式中 Eha 是晒田前土壤 pH7 時之還原電位，OM 是表土有機質含量，K 是有效性鉀，SC 是土類（SSA、SA、SSSA、RE、EMA、ScA 及 TCA 各以1、2、3、4、5、6及7代表），T是表土質地（LS～SL、SiL、L、SiCL 及 SiC 各以3、4、5、7 及 8代表）。（9）～（12）式指出一期作時，OM、K 和 SC 最能預估 Eha，加上 pH 及 T，可以預估 35%。（13）及（14）式指出二期作時，SC 及 T 即有 30%之預估能力。雖然未達50%以上預估能力，但是此五種都是很穩定的土壤基本性質，且統計上均達 1 %顯著水準，故對預估 Eha 仍頗有價值。例如（11）式，表土有機質 4 %比 1 %之 Eha 低 100 mV，片岩冲積土（ScA）比砂頁岩冲積土（SSA）更還原 50 mV，亦即富含有機質的片岩冲積土稻田易發生過度還原問題。

三、水分管理對土壤還原電位和水稻產量之影響

稻田水分管理旨在探討不同灌溉（或晒田）方式對土壤還電位（Eh）和水稻產量之影響，以建

Table 5. Effect of water management on soil redox potential (mv)

Year	Crop	W_1		W_2		W_3	
		Before drying	After drying	Before drying	After drying	Before drying	After drying
1981	2nd	− 61	− 17	− 88	− 71	− 122	− 76
1982	1st	131	− 121	144	− 138	149	− 143
1982	2nd	− 231	− 123	− 202	− 120	− 252	− 129
1983	1st	72	− 113	45	− 93	80	− 79

立合理的水分管理方法。從表5發現土壤 Eh 有下列現象。1.晒田前土壤 Eh，一期作時保持正值，表示土壤不太還原。二期作時均為負值，尤其是 71年二期作更低於 −200mV，顯示土壤相當還原。2.晒田後土壤 Eh，一期作在 −79～−143mV，二期作在 −17～−129mV。一期作晒田後土壤 Eh 反而下降，乃因氣溫上升所致。二期作晒田後土壤 Eh 顯著上升，乃因晒田的效應。3.三種水分管理之晒田對土壤 Eh 的效應雖無明顯差異，但確能提高二期作之土壤 Eh。

Table 6. Effect of water management on grain yield

Year	Crop	W_1		W_2		W^{ε}	
		kg/ha	index	kg/ha	index	kg/ha	index
1981	2nd	4,772	107	4,974	111	4,475	100
1982	1st	7,657	100	7,601	99	7,690	100
1982	2nd	6,005	106	6,223	109	5,684	100
1983	1st	5,864	98	5,944	99	5,990	100

* The yield index of W_3 used as 100.

關於水分管理對水稻產量之影響，表 6 指出間歇灌溉的水分管理 W_1 及 W_2 較有利於二期作水稻的生產，但對於一期作却沒有明顯影響。70 年二期作間歇灌溉處理 W_1（晒田 5～6 次）及 W_2（晒田 3～4 次）比推薦法（晒田 1 次）可增產稻穀 7 及 11%，71 年二期作亦可增產 6 及 9%。在統計上，70年二期作，W_2 優於 W_1，W_1 優於 W_3，均達 5%顯著水準。71 年二期作，W_2 優於 W_3，達 1%顯著水準。但是71年及72年一期作，三種水分管理對水稻產量沒有明顯影響。

綜合言之，本省二期作時，稻田土壤 Eh 偏低，已有過度還原現象，且晒田確能提高土壤 Eh 而降低過度還原的危害。雖然三種水分管理之晒田對提高土壤 Eh 效應上沒有明顯區別，但仍以 W_2 之間歇灌溉管理（浸水至插秧後40～50日，然後晒田至土壤水分張力 0.2bar 時再灌溉，依此方式管理至黃熟期）最有利於二期作水稻生產。

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Identification of Redox Potentials of Paddy Soils in Taiwan and Its Application to Water Management for Lowland Rice[1]

M. H. Haung[2]

Summary

This study was conducted to investigate the distribution of redox potentials(Eh) of paddy soils in Taiwan and its effect on the growth and yield of rice. A field trial on water management was carried out simultaneously in the experimental farm of this Institute to compare the influence of drying on Eh changes and the growth and yield of rice. The results are summaried as follows:

1. During the 1st crop, Schist Alluvial soil(ScA) and East-coast Mother rock Alluvial soil (EMA) were easier to bring about higher reduction. During the 2nd crop, soil Ei_7 (Eh at pH 7) of all the soil categories were below −150mv before drying. It indicated that all the soil categories were already highly reduced during the active tillering period of the 2nd crop.
2. For the 1st crop, the correlation coefficient between soil Eh and grain yield was positively significant($r=0.24^*$) before drying, while the correlation coefficient between soil Eh and grain yield was positively significant ($r=0.34^*$) after drying for the 2nd crop. It shows that soil Eh is an important factor affecting the growth and yield of rice. It also indicates that soil Eh should be measured before drying for the 1st crop, while soil Eh should be measured after drying for the 2nd crop.
3. Drying (drainage to 0.2 bar soil moisture tention) is effective to increase soil Eh. For the 2nd crop, the water management of intermittent irrigation (W_2) Was the most beneficial method. The grain yield of W_2 was more than that of standard method (W_3) by 10%.

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温度與照度對螺旋藻生長速率、生理與生化性質之影響

劉　慧　瑛

摘要：食用性高蛋白質螺旋藻 *Spirulina platensis*, 爲一絕對光自營性生物，除了照度因素外，溫度、接種濃度與培養方式對其生長都有重要的影響。劇烈的攪拌會減弱藻體對高溫及强光的耐性而使生長速率變慢。太過稀薄的藻體則在40°C及强光下生長時會迅速進入衰減期；然而，提高溫度至40°及45°C時可使較高濃度的藻體得到較大的生長速率與較小的飽和光量。

初濃度約0.24g/l之對數生長期螺旋藻培養液在 33—45°C 與1—16 klux 環境下培養24小時，經一般組成與色素成分分析後發現，在强光高溫下生長之藻體，其細胞內除全醣量大幅增加外，蛋白質、核酸、葉綠素 a 、類胡蘿蔔素及藻藍素含量均行減少且失去上浮能力；在顯微鏡下可觀察到細胞顆粒及氣胞數目減少呈透明狀態；靜置培養之藻體細胞總長度達２－３毫米，通氣攪拌則導致細胞嚴重斷裂；單位培養體積內之總醣量高出低溫弱光培養者約 30—35 倍，除葉綠素 a 減少，藻藍素不增減外，其餘成分都有增加。

在 37°C, 6 klux 或 40°C, 4—6 klux下，以靜置方式培養螺旋藻時可以得到最大的蛋白質、葉綠素 a 及藻藍素產量。

螺旋藻（Spirulina）係一新開發之食用高蛋白質藍綠藻（Blue-green algae）。在自然界中所存在的螺旋藻雖有三十餘種[15]，而以法國石油研究所與日本中村浩自非洲內陸 Chad, Aranguadi 湖分離出之*S. platensis*及自墨西哥SOSA Texcoco碱業公司碳酸鹽蒸發池中分離得到之*S. maxima* 被認爲最具生產價值[2,15]。除了非洲Kanem族[10,15]與墨西哥 Aztek 族[2,15]人民已有食用該藻數千年之歷史外，法國、墨西哥與日、美、俄、西德等國一些學術研究機構自十五年前開始紛紛進行種種培養、生化及營養試驗，證實其具有高營養價值且食用安全無虞[4,15]。

就該藻之天然生育環境觀察，此藻適合在高溫及陽光充足的地區生長，目前除了墨西哥採用半天然（semi-natural）方式培養[2,26]，年產可達五百噸外[26]，在臺灣[1]及琉球（由日本投資經營）[3]均已進行人工化大規模培養生產。螺旋藻培養雖以方法簡易著稱，實際上室外生產單位面積產量僅及綠藻之半[27]。就藻體營養價值、經濟用途及生產潛能而言，螺旋藻優於綠藻，所以，提高螺旋藻生長速率並控制成品品質，可使其成爲一種高營養的廉價蛋白質資源與生質（Biomass）能源。

對於培養條件之探討，Meyer[20], Nguyen[21]與Ogawa[22,23,24]等人均著重於常溫或最適生長溫度（Optimum Temperature）下藻體生長情形及一般成分分析之研究。Ogawa 氏研究 35°C下*S. platensis* 之生長動力學[23]，並探討不同照光強度（Light Intensity）對細胞色素變化之影響[24]。Van Eykelenburg則研究15°至 39°C與0.3至21 klux 照度下細胞產量與內部微細構造之差異[28,29,30]。有關溫度與照度變化對此藻一般組成分，色素成分，礦物質含量等品質影響並未被分析研

1.臺灣省農業試驗所　研究報告第 1168 號。本文獲國科會71年度研究成果奬助。

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究。由於 *S. platensis* 較適合在30°C以上高溫下生長，且夏季臺灣水溫或可高達 40°C，因此本試驗旨在探討超適溫度（30° 至 45°C）下，不同照度與溫度對藻體生長速率、產量、蛋白質（Protein）、核酸（Nucleic Acid），全醣（Carbohydrate）、葉綠素 a （Chlorophyll a）、類胡蘿蔔素（Carotenoid）、藻藍素（C-Phycocyanin）含量及其它生理特性之影響，俾能求得提高藻體生長速率與品質之方法。

材料與方法

一、使用藻種：*Spirulina platensis* 與 *S. maxima* 係臺灣大學蘇遠志教授及前聯合工業研究所所長郝履成博士慨贈。

二、培養基組成：將Zarrouk氏培養基組成[33]加以修飾如下：

表一：合 成 培 養 基 組 成

Table 1：The composition of synthetic medium

$NaHCO_3$	8.4 g/l	K_2HPO_4	0.25 g/l
$NaNO_3$	1.5	K_2SO_4	0.5
NaCl	0.5	$MgSO_4 \cdot 7H_2O$	0.1
$CaCl_2$	0.015	$FeSO_4 \cdot 7H_2O$	0.0
E. D. T. A. -2Na.	0.08	A_5 soln.	0.5 ml./l
B_6 soln	0.5ml./l		

a A_5 soln. (g/l)：H_3BO_3 2.85, $MnCl_2 \cdot 4H_2O$ 1.81, $ZnSO_4 \cdot 7H_2O$ 0.22, $CuSO_4 \cdot 5H_2O$ 0.08, MoO_3 0.15

b B_6 soln. (g/l)：NH_4VO_3 0.023, $K_2Cr_2(SO_4) \cdot 24H_2O$ 0.096, $NiSO_4 \cdot 7H_2O$ 0.048, $Na_2WO_4 \cdot 2H_2O$ 0.018, $Co(No_3)_2 \cdot 6H_2O$ 0.044

三、靜置培養：將含有對數生長期（Log Phase）藻體之培養液 300c.c. 裝入直徑九公分之平底棕色圓玻璃盆中，置於大型植物生長箱內，由上方以60W日光燈照射培養，每隔約四小時攪拌一次。

四、通氣培養：將含有對數生長期藻體之培養液 250c.c. 裝入 500c.c. 三角瓶內，加上通氣管塞後置於恆溫箱內，以熱帶魚養殖用送風幫浦通氣攪拌（通氣量約1.5vvm），並以 4 支 20W日光燈由底部照光培養。

五、照度測定：以東京光電照度計 ANA—300 型測定之。文中以I（Intensity of light, KLUX）表示之。

六、藻體濃度測定：將培養液置於 1 公分或 5 公分寬之石英管中，以 HITACH Model 124 Double Beam Spectrophotometer測定在波長560nm時之吸光密度（OpticalDensity 或Absorbance）值，而以$O.D._{560}$（d=1cm）表示之。藻體接種後之初濃度則以 X_0 表示。藻體乾重（Dry Cell Weight，簡稱D. C. W.）則以下式計算：$D.C.W._{(mg)} = 0.55 \times O.D._{560} \times$ 體積（c. c.）

七、藻體前處理：取 100c.c. 藻體培養液兩組，以濾紙過濾並洗滌後，一將濾紙浸入80%丙酮液中萃取脂溶性色素；一將濾紙上藻體以蒸餾水洗至塑膠杯內，放入凍庫，俟其凍結後再予取出解凍。以Ultrasonics Co. Sonicator Cell Disruptor Model W-220F 超音波震盪處理 2 — 3 分鐘後，將細胞溶液洗至定量瓶中，分析其藻藍素、蛋白質、核酸及全醣含量。

八、色素吸光光譜測定：以 HITACHI Model 124 掃描式 UV-Vis. Spectrophotometer，光柵（slit）1nm，掃描藻色素液在330至750 nm之吸光光譜。

九、蛋白質測定：依據Lowry et. al.（19）方法加以修飾測定。試劑中之Na-tartrate以Na-Citrate取代。

十、核酸測定：以0.25 N $HClO_4$ 萃取三十分鐘後測其在260及280 nm 的紫外吸光密度並代入下式計算核酸濃度：

Nucleic Acid (mg/c.c.) $= 0.063 O.D._{260} - 0.036 O.D._{280}$ [8]

十一、全醣量測定：以酚—硫酸法測定之[11]。

十二、總蛋白質、核酸、全醣量測定：以下式計算

單位體積內各成分總量 (mg/l)

$= O.D._{560} \times 0.55 \times$ 體積 (c.c.) × 各成分含量 (%)

十三、葉綠素a測定：取80%丙酮抽出液，測其在660及730 nm之吸光密度，代入下式：

Chlorophyll $a_{(mg)} = 10 \times v \times f \times (O.D._{660} - O.D._{730})/890$ [16]

(v：溶液體積c.c. 數，f：稀釋倍數，葉綠素a吸光常數$\varepsilon^{1\%}_{1cm} = 890$)

十四、藻藍素測定：取細胞溶液測定其在620及750 nm之吸光密度，代入下式：

Phycocyanin (mg) $= 10 \times v \times f \times (O.D._{620} - O.D._{750})/73$

藻藍素吸光常數$\varepsilon^{1\%}_{1cm} = 73$ [6]，此測定值中並未包含 Allophycocyanin與Phycoerythrocyanin含量)

十五、類胡蘿蔔素測定：取80%丙酮抽出液，測其在475及730 nm之吸光密度，代入下式：

Carotenoids (mg) $= 10 \times v \times f \times (O.D._{475} - O.D._{730})/2500$ [16]

(類胡蘿蔔素吸光常數 $\varepsilon^{1\%}_{1cm} = 2500$)

十六、上浮率 (Floating Ratio) 測定：取10c.c. 培養液置於內徑 12mm之試管中，測其在 560nm 之吸光密度值 ($O.D._{560}$) 而以D_0表示之。靜置一小時後取上層兩毫升液，測定其 $O.D._{560}$值，以D_1表示；代入下列公式：

Floating Ratio (%) $= (D_1 \times 2)/(D_0 \times 10) \times 100\%$

結果與討論

一、溫度與照度對藻體生長速率之影響：

螺旋藻為一絕對光自營性生物 (Obligate autotroph)[22]，能夠利用CO_2、HCO_3^- 等無機碳源進行光合作用而生長，然而在無光照環境下，不能利用有機碳源如葡萄糖、醋酸等以維持生命。*S. platensis*與*S. maxima* 均適合在30至37°C 下生長，而以前者較耐高溫與強光。由於本試驗中所培養之*S. maxima*在16 Klux, 40°及45°C下均發生光分解死亡現象，因此僅以 *S. platensis* 作為探討對象。

將不同接種濃度之藻體培養液置於 40°C 下以日光燈照射培養 24 小時，照度分別為 4，6 及16 Klux，測定藻體在 6 及24小時之$O.D._{560}$值。結果由圖 1 培養時間與藻體濃度關係可以看出照度愈強時生長也愈快；接種濃度愈高則藻體產量也愈大；不過接種濃度太稀薄 ($X_0 = 0.023$) 時藻體初期生長雖快，然而培養至24小時生長反而緩慢。

依據Ogawa & Terui氏之研究，藻體在 40°C 之比生長速率 (Specific growth rate, μ) 低於在35—37°C下生長者[23]，而Van Eykelenburg則以31°C為 *S. platensis*最適生長溫度[28]。將不同接種濃度之藻體培養液置於 37°, 40° 及45°C下，以 4，6，16 klux 之照度培養24小時，則試

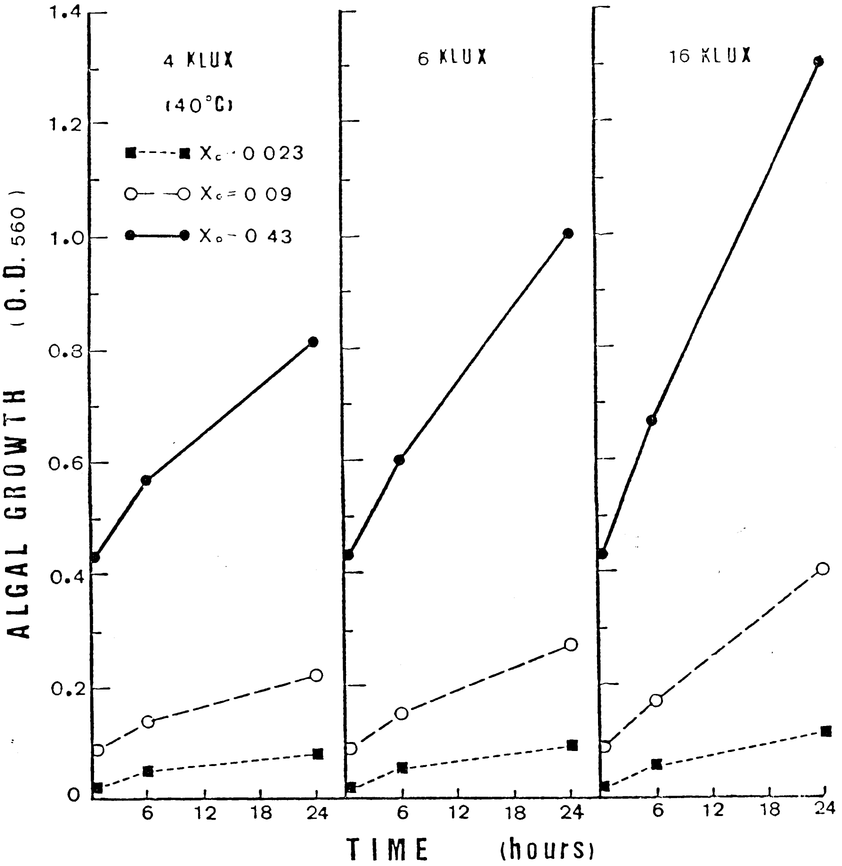


圖 1 ：不同接種量與不同照度下螺旋藻生長情形

Fig. 1 ; Time courses of Spirulina growth with various inoculum sizes and with various light intensity.

驗結果顯示溫度愈高，照度愈强時，藻體產量（以藻體乾重表示）增加愈多。由圖 2 不同照光强度與

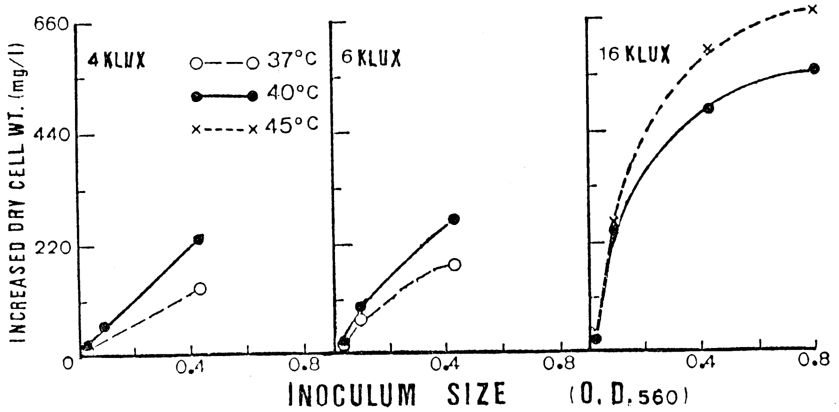


圖 2 ：不同溫度與照度下，螺旋藻接種量與藻體乾重增加量之關係

Fig. 2 ; Effect of Inoculum size on Spirulina production in various temperature and cultural light intensity.

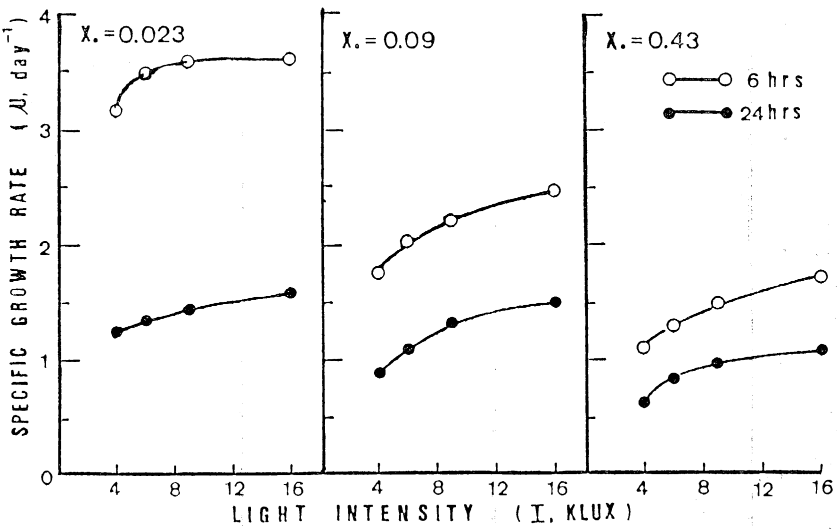


圖 3 ：不同螺旋藻接種量下，照度與藻體比生長速率之關係

Fig. 3 : Effect of cultural light intengity on the specific growth rate of *Spirulina platensis* with various inoculum sizes.

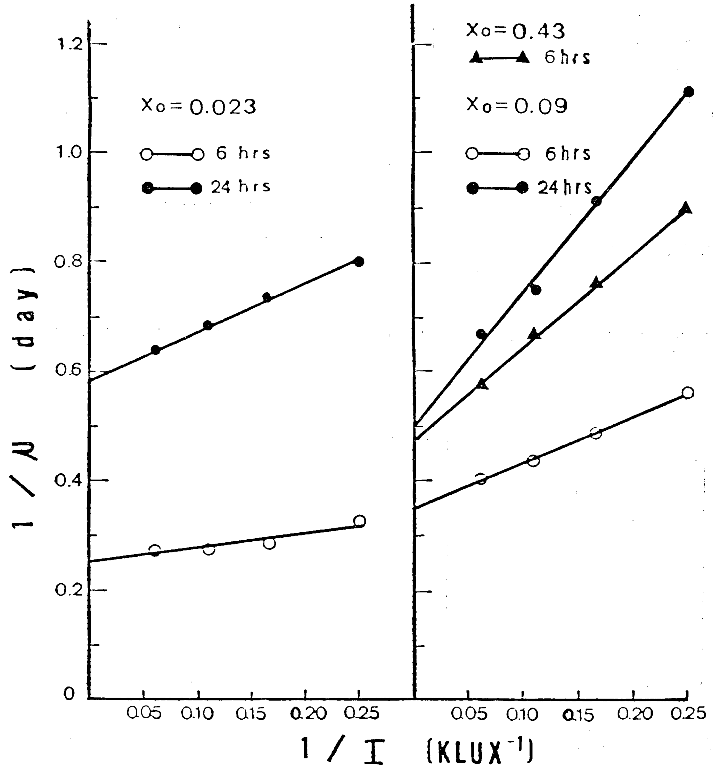


圖 4 ：對數生長期藻體之照度倒數與比生長速率倒數作圖

Fig. 4 : Lineweaver-Burk plot for the effect of light intensity (I) upon pecific growth rate (μ) with various inoculum sizes of *Spirulina splatensis*.

溫度對藻體乾重增加量之影響可見，於16 klux照度下45°C 優於 40°C，而在 6、4 klux 照度下亦以40°C優於37°C者。

關於藻體生長動力學之研究，Ogawa 氏認為在營養條件充分之環境下，對數生長期中之藻體，其比生長速率 (μ) 與入射光强度 (I_o) 符合Monod-Type方程式 $\mu=\mu max\ I_o/(I_o+K_L)$, μmax 為最大比生長速率，K_L 為飽和光常數[24]。圖 3 所示即不同接種濃度及培養時間下所求得之比生長速率與照度之關係，藻體濃度愈稀薄，比生長速率也愈大。6 小時培養所得藻體比生長速率大於24小時者；濃度愈稀兩者差異也愈大。根據 Lineweaver-Burk公式$1/\mu=1/\mu max+K_L/I_o$作圖，以比生長速率與照度之倒數分別作為縱軸及橫軸時可以求出各生育條件下之最大比生長速率（縱軸交點）及飽和光常數（橫軸交點）。由圖 4 比生長速率倒數與照度倒數之關係所求得之各培養條件下之μmax 與K_L值示於表 2。根據Ogawa氏報告，在35—37°C下以極稀薄之藻體培養所得到 之μmax 為2.2day^{-1}, K_L為6.7klux[23]。將其μmax 值與本次試驗所得結果相比較則發現，在較高溫度（40°C）下培養可使較高濃度的藻體（$X_o=0.09$, 6小時；$X_o=0.43$, 6小時）得到相近的比生長速率，且減少對光照度的需求量（K_L 分别為 5 及 3.6klux）。又，以 $X_o=0.023$ 培養時，雖然 6 小時培養結果可以求得μmax 為4.0day^{-1}，亦即間隔約 6 小時細胞分裂一次，由於藻體濃度太過稀薄，本試驗中僅取用吸光密度法測定，誤差甚大，須經精確測定後再予證實。

表二：最大比生長速率與飽和光常數

Table 2: Maximum specific growth rate and light intensity saturation constant calculate d from fig. 4

Inoculum Size (X_0, O. $D._{560}$) \ Time \ Items	Maximum Specific Growth Rate (μ, day^{-1})		Saturation constant of light intensity (K_L, Klux)	
	6 hours	24 hours	6 hours	24 hours
0.023	4	1.7	1	1.5
0.09	2.8	2	1.5	5
0.43	2.1	—	3.6	—

$X_o=0.023$培養24小時後O. $D._{560}$值達到0.11而其μmax却少於 $X_o=0.09$者，由於照度不成為其生長限制因子，因此顯示出在培養後期，細胞內部代謝發生變化，無法維持對數期生長而進入安定期（Stationary phase）或衰減期（Decline phase）。由圖 1藻體生長情形亦可看出，接種濃度太低時，藻體不適宜在40°C下生長。

二、溫度與照度對藻體細胞組成分之影響：

將接種濃度 $X_o=0.43$ 之藻體培養液置於不同溫度及照度下培養24小時後測定其藻體產量，蛋白質、全醣及核酸含量等，並計算藻體之比生長速率值，結果如圖 5 所示，光照强溫度高時比生長速率大，全醣含量增加而蛋白質與核酸含量降低。

在碳源利用上，大幅度增加之藻體全醣量正可說明在高溫强光下，光合作用旺盛進行。

反之，藻體蛋白質含量減少則可能是由於氮源缺乏，氮同化作用（Nitrogen assimilation）緩慢，呼吸作用（Respiration）快速等因素所引起。本試驗中並未有氮源缺乏現象，且 Van Eykelenburg 亦以試驗結果說明增加硝酸鹽濃度可以提高藻體在35°C以上溫度生長時之產量及生長速率[30]，因此推斷氮同化速率趕不上光合作長速率是藻體蛋白質含量遽減之主因。 Faucher et. al 等研究*S. maxima*對尿素之利用發現該藻對尿素吸收情形較硝酸態好。[13] 作者亦對 *S. platensis* 進行氮源利用試驗發現其對氨態氮如氨水、硫銨及尿素等吸收最快，其次為亞硝酸態氮，再次為硝酸態氮；即

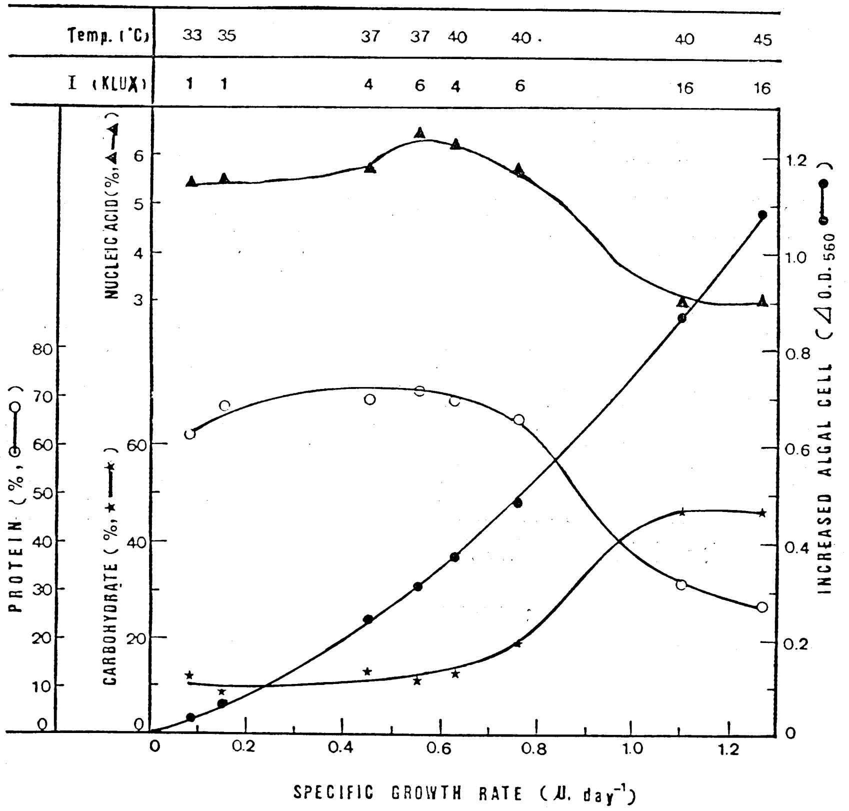


圖 5：不同溫度與照度下，藻體之比生長速率，O. D.560增值與蛋白質、全醣及核酸含量關係圖

Fig. 5: Effect of specific growth rate, temperature and light intensity upon protein, nucleic acid and toal carbohydrate content in algal cell.

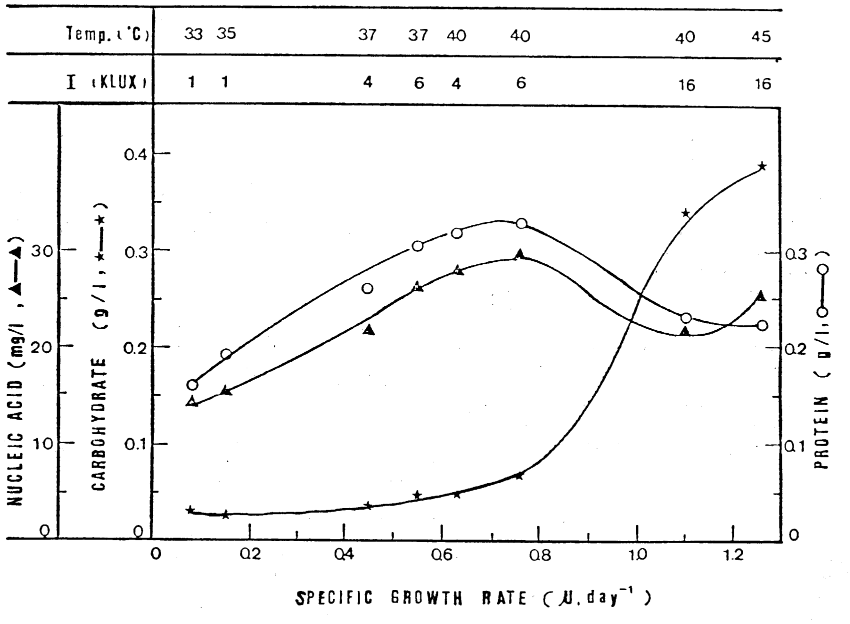


圖 6：不同溫度及照度下，螺旋藻培養液中所含蛋白質、核酸與全醣量和藻體比生長速率之關係

Fig. 6: Effect of specific growth rate, temperature and lignt intensity upon protein, nucleic acid and carbohydrate amounts in Spirulina cultural medium.

令在常溫下培養，當藻體接種入新的培養基（僅含硝酸態氮源）時，蛋白質含量會下降10至20%左右後再逐漸上升。本試驗係以硝酸鈉作爲唯一氮源。

又Verstreate等研究藍綠藻*Anabaena flos-quae*之生長及對硝酸鹽之利用時指出培養液內鐵濃度影響硝酸鹽之吸收[31]。由於光合作用旺盛時，能量轉移系統需要大量的鐵離子參與其事，此可能導致培養液內鐵濃度缺乏，不足藻體所需，間接影響硝酸鹽的吸收而使氮同化速率趕不上光合作用速率，以致全醣量大增而蛋白質量減少。所以，要提高藻體在 40°C 以上溫度及强光下生長時，使用氨態氮或增加鐵濃度是提高藻體蛋白質含量及維持正常生長之可能方法。

由上述藻體組成分分析結果計算出單位體積內總蛋白質、核酸及全醣量，其與溫度及照度之關係示如圖 6。單位體積內全醣量在高溫强光下之增加量可達中溫低照度者之30至35倍，碳素固定量高達約0.14g/l/day培養深度以2.5—5.0公分計算時相當於 3.5—7.0g/m²/day。又由總蛋白質及核酸量之增減情形可知單位體積內藻體蛋白質與核酸量均有增加，而以40° C, 6klux培養時產量最大。

三、溫度與照度對藻體色素組成之影響：

將前述培養條件下之藻體分別取得其脂溶性色素，及含有各種色素之細胞水溶液，掃描 750nm至330nm之波長後求得其吸收光譜。結果如圖 7a, b及圖8a, b所示。由圖7a脂溶性色素在照度不同下

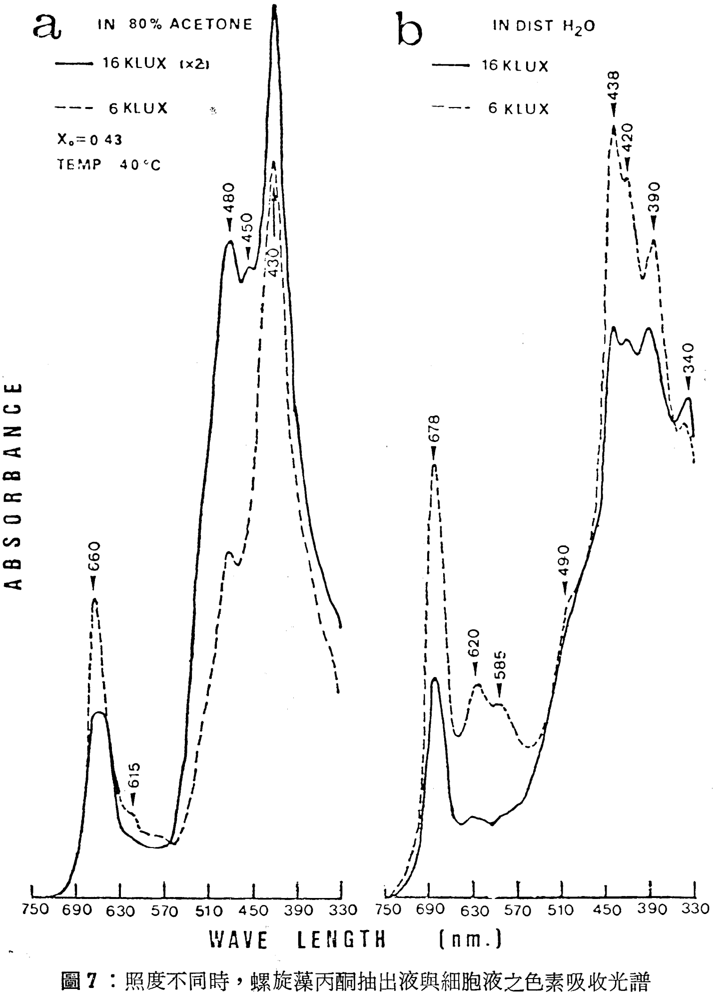


圖 7：照度不同時，螺旋藻丙酮抽出液與細胞液之色素吸收光譜

Fig. 7: Absorption spectra with acetone extracts and cell suspension from *S. platensis* cells grown illuminated at 6 and 16 Klux.

之變化情形可以看出葉綠素a吸光（660及 430nm）密度大量減少，而類胡蘿蔔素吸光（510至340nm）變化程度較小。表 3 所示爲 *S. platensis* 在常溫狀態下培養時所含有之類胡蘿蔔素組成。表 4 所示則爲該類胡蘿蔔素在丙酮及正乙烷（n-Hexane）中最大吸收波長。

表三：螺旋藻之類胡蘿蔔素組成

Table 3 : The composition of carotenoids of *S. platensis*

Items / Sample	A[5]	B[15]	C[25]
β-Carotene	38.5(%)	42.5(%)	71 (%)
Cryptoxanthine	5.0	13.9	
Echinenone	5.3	11.0	12.5
Lutein and Euglenanone	—	7.2	
Physoxanthine	—		6.25
Xanthophylls	—	25.0	
β-Zeacarotene			2.5
Zeaxanthine	35.4	7.9	7.75
Unidentified degradation products of carotenoid	17.0		
Total amounts of carotenoids (mg/kg)	1,071	4,000	6,000

表四：螺旋藻體內所含類胡蘿蔔素之最大吸收波長

Table 4 : Principal absorption maxima of some carotenoids[9] presented in *S. platensis*

Carotenoids	Maximum absorption (nm.)			Solvent
β-Carotene	(429)	452	478	acetone
β-Carotene	(425)	450	477	n-Hexane
Cryptoxanthin		446	475	n-Hexane
Echinenone		460		acetone
Echinenone	(432)	459	(483)	n-Hexane
Lutein	(420)	44	475	n-Hexane
Myxoxanthophyll	(450)	478	510	acetone
Oscillaxanthine	470	499	534	acetone
Physoxanthine		445	474	n-Hexane
β-Zeacarotene	407	427	454	n-Hexane
Zeaxanthine		452	479	acetone
Zeaxanthine	424	449	476	n-Hexane

圖 8a 所示爲不同接種濃度之藻體在 16klux, 40°C 下生長時脂溶性色素液之吸收光譜。與圖7a比較結果可以發現藻體接種量大（如 X_o=0.8）時，所受到的光照量小，近似於稀濃度藻體（如X_o=0.43）在低照度（6klux）下生長之結果。臺灣夏季中午日照強度高達 110klux ，爲充分吸收日光能及避免葉綠素受强光破壞，應該提高培養液中藻體濃度在O. D.$_{560}$值0.8以上。

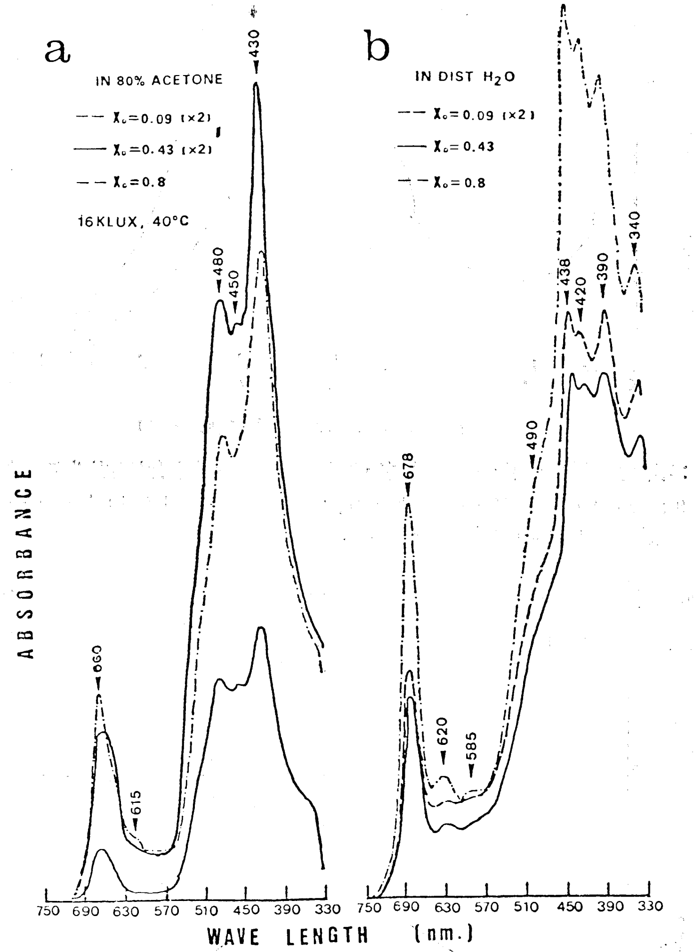


圖 8：螺旋藻接種量不同時，藻體丙酮抽出液與細胞液之色素吸收光譜

Fig. 8: Absorption spectra with acetone extracts and cell suspension from *S. platensis* cells grown with various inoculums izes.

細胞水溶液吸收光譜（圖7b及8b）即藻體細胞色素懸浮液之吸收光譜。照光强度增加時，水溶性藍色色素如藻藍素（C-Phycocyanin, 620nm）與藻紅藍素（Phycoerythrocyanin, 585nm）含量亦呈大量降低，在類胡蘿蔔素與葉綠素a色素吸收區域中490，438，420，390及340nm 等波峰之吸光密度亦亦因照度不同而有不同的變化。

在不同溫度及照度下生長之藻體，其葉綠素 a、類胡蘿蔔素其藻藍素含量分佈情形示如圖 9。由此圖中可以看出藻體所含葉綠素 a 與藻藍素在强光培養下急遽減少，而類胡蘿蔔素含量呈少量減少；

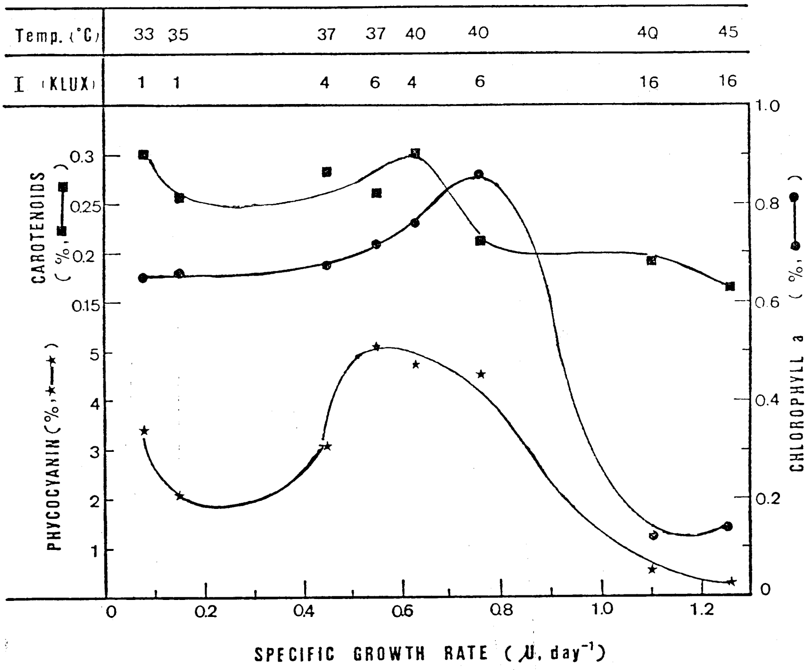


圖 9：不同溫度及照度下，藻體葉綠素，類胡蘿蔔素與藻藍素含量和比生長速率之關係

Fig. 9：Effect of specific growth rate, temperature and light intensity upon pigment content in algal cells.

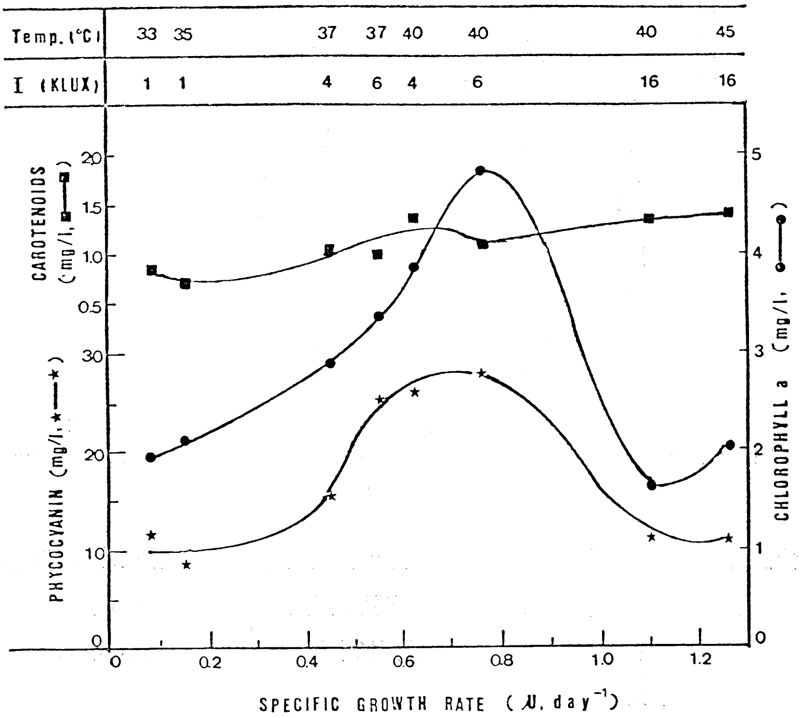


圖10：不同溫度及照度下，螺旋藻培養液內所含葉綠素，類胡蘿蔔素與藻藍量和比生長速率之關係

Fig. 10：Effect of specific growth rate, temperature and light intensity upon pigment amounts in Spirulina cultural medium.

此結果與Kratz & Meyers氏對*Anacystis nidulans*色素在强光下變化之硏究結論[17]相同。圖10所示則爲不同生長條件下單位體積內各色素成分總量與比生長速率、溫度及照度之關係。由該圖中可以看出僅葉綠素總量在强光下減少，藻藍素沒有增減而類胡蘿蔔素含量增加，因此可以推測各成分之生合成速率比不上藻體生長速率而使得攪體內色素含量減少。

藻藍素係由藻藍胆素原（Phycocyanobilin）與大分子之蛋白質緊密結合而成，强光下藻藍素含量減少與圖 5 所示之蛋白質含量減少，可能互有因果關係。 Boussiba 等，即認爲藻藍素是一種蛋白質的貯藏形式[7]。

四、溫度與照度對藻體上浮之影響：

S. platensis 與 *S. maxima* 生理特性之一大差異即前者具有上浮能力而後者則無。 Van Eykelenburg氏發現 *S. platensis* 會形成圓柱形之氣胞（Gas vacuole或Gas Vesicle)[29]。Walsby氏硏究氣胞膜的構造認爲幾乎全由蛋白質分子所構成；在光線微弱或藻體老化時，細胞內氣胞數目會增加[32]。有關此藻上浮能力之硏究，尙無資料可循。圖11 所示爲不同溫度及照度下生長之藻體，其上浮率與比生長速率、蛋白質含量之關係。由此圖中可以看出蛋白質含量與藻體上浮率似成正比關係。圖 5 所示强光下藻體蛋白質量減少，除了藻藍素合成速率受影響外，氣胞膜蛋白不能形成亦爲可能因素之一。

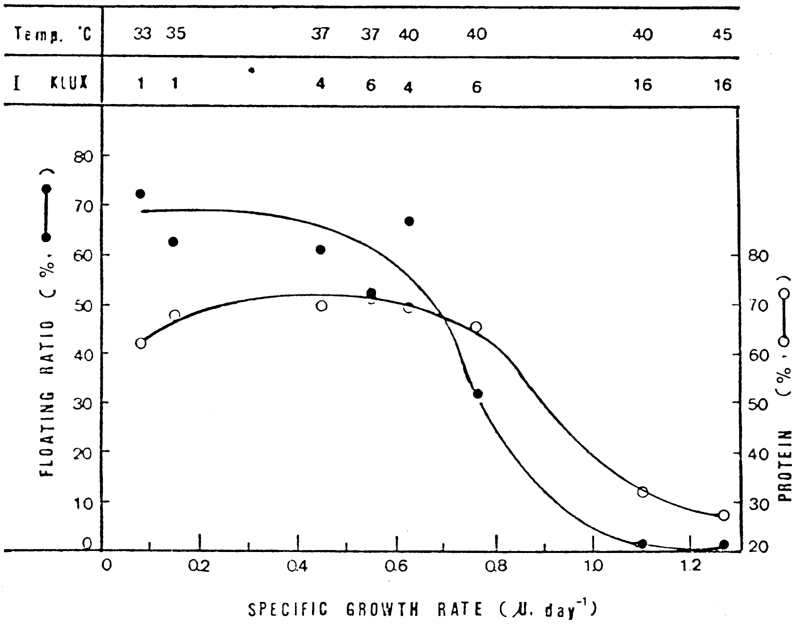
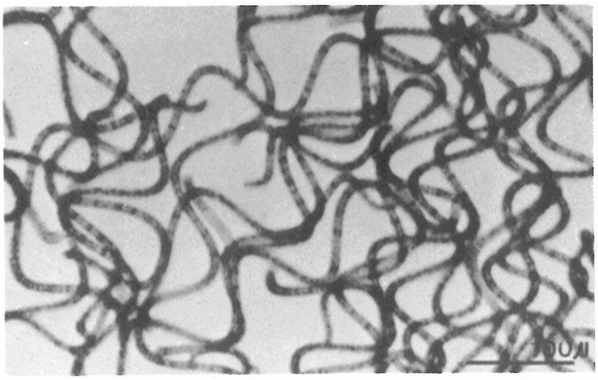


圖11：不同溫度及照度下，螺旋藻上浮率及蛋白質含量與比生長速率之關係

Fig. 11: Effect of specific growth rate, temperature and light intensity upon floating ratio and protein content of *S. platensis*.

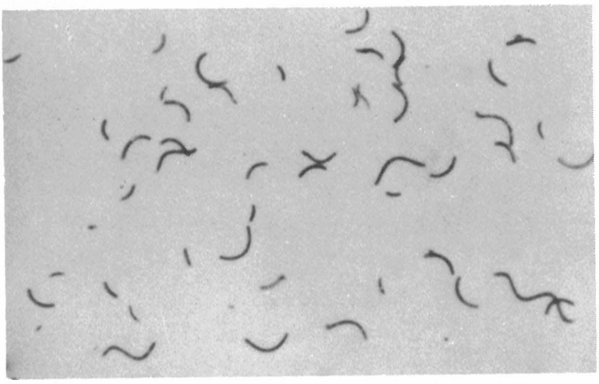
五、培養方式對藻體生長及生理之影響：

Ogawa 氏認爲溫度大於37°C時藻體生長反而減慢[23]，然而依據本次試驗結果顯示*S. platensis* 即使在45°C, 16klux 下亦能快速繁殖，Ogawa 氏係使用振盪方式培養。表 5 所示即以通氣攪拌與靜置培養方式比較藻體生長結果。由此表中可以看出，强光高溫下通氣培養之藻體生長較慢，然而其細胞組成分與色素含量則與靜置培養所得結果相近。低照度培養時，通氣藻拌與靜置培養之藻體生長差異較小。



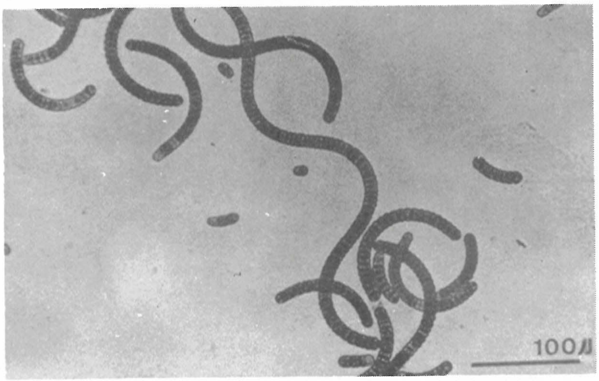
圖十二：40°C,16klux 靜置培養24小時（×200）

Fig.12：*S. platensis* grown with sedimentation 40° C, 16 klux (×200)



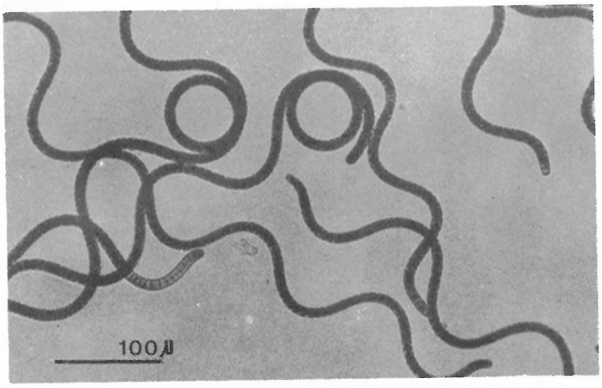
圖十三：42 °C, 9klux 通氣培養 24 小時（×40）

Fig.13：*S. platensis* grown with aeration, 42° C,9 klux (×40)



圖十四：40 °C, 6 klux 通氣培養 24 小時（×200）

Fig.14：*S. platensis* grown with aeration 40°C,6 klux (×200)



圖十五：40°C, 4klux 靜置培養24小時（×200）

Fig.15：*S. platensis* grown with sedimentation 40°C, 4klux (×200)

表五：不同培養方式下藻體之生長與細胞組成分分析

Table 5: Growth rate and cellular compostion of *S. platensis* grown in different cultivating treatment

Growing type	Temperature (°C)	Illumination (Klux)	Inoculum size (O. D. 560)	Growth Rate (μ)	Floating ratio (%)	Nucleic acid (%)	Protein (%)	Carbohydrate (%)	Chlorophyll a (%)	Carotenoids (%)	Phycocyanin (%)
Sedimentation	45	16	0.09	1.58	2		31.58	52.92			
	40	16	0.09	1.54	1	4.19	33.92	52.38	0.22	0.22	1.58
	40	16	0.43	1.27	3	3.03	31.92	47.69	0.22	0.19	1.47
	40	6	0.43	0.99	32	5.83	65.82	13.37	0.96	0.21	5.48
Air-bubbling	42	9	0.23	0.42	2	4.90	27.42	45.83	0.24	0.22	1.38
	40	6	0.23	0.85	55	6.09	62.50	27.22	0.75	0.25	2.10

在光學顯微鏡下觀察強光高溫下靜置培養之藻體，發現細胞延伸至全長達 2～3mm，螺紋數三、四十，細胞甚少斷裂，許多部分呈透明狀態，顆粒減少（見圖12），顯示藻體色素顆粒與氣胞數目減少。以通氣方式培養之藻體則斷裂成小段（見圖 13,14）。將高溫強光下生長之藻體放入凍庫再予解凍時，細胞容易破碎，然而在低照度下生長之藻體（見圖15），並無此現象。由此可知藻體在高溫強光下生長時，細胞比生長速率雖大而易破裂損傷，因此不宜採用較激烈的攪拌方式，以免對藻體造成物理傷害，如此則可使藻體維持正常生長。

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Studies on the Effects of Temperature and Light Intensity upon Growth Rate, Physiological and Biochemical Characteristics of *Spirulina platensis*

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Summary

Edible blue-green alga, *Spirulina platensis*, rich in protein and carotenoids, is an obligate photo-autotroph. Not only light intensity, but also temperature, inoculum size and cultivating type affect the growth of this alga. Violent agitation would decrease the resistance of high temperature and strong illumination, then slow down the growth rate. Too diluted inoculant and strong illumination at 40°C would quickly make the algal growth approaching to decline phase. However, the maximum algal growth rate and lesser saturation constant of light intensity could be obtained with dense inoculant and increasing the cultivation temperature to 40° and 45°C.

Spirulina grown in exponential phase with inoculum size about 0.24g/l were cultivated under 33°-45°C and 1-16 Klux for 24 hours. After analyzing the cellular composition and pigment content, it was found that algal cell grown with high temperature and light intensity had extremely high carbohydrates content, but less in protein, nucleic acid, chlorophyll a, carotenoids and c-phycocyanin content and lost floating ability. Under microscopic examination, the cell was transparent, contained few granules, formed short fragments in aeration culture and very long [2-3mm. in length] in sedimental cutlure.

Comparison the medium for Spirulina grown in high temperature and strong light with low temperature and dim light, it was found that the amount of total carbohydrates presented in unit volume medium of the former was 30 to 35 folds, chlorophyll a was fewer, c-phycocynin was equal and other components were more than that of the latter.

Maximal production of protein, chlorophyll a and c-phycocyanin in Spirulina could be harvested with sedimental cultivation at 37°C and 6 Klux or at 40°C and 4-6 Klux.

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低海拔香菇品系之育種[1]

廖 英 明[2]

摘要：由臺灣採集之野生香菇５種，取其子實體所得之單核菌絲各10個，與４種日本野生品系及６種日本栽培品系進行什交試驗，共得５×10×10個什交組合。經培養後檢查其扣子體產生情形，得到 162個什交雙核體可產生扣子體，再進行菌絲培養試驗及低溫下產生原基體能力之測定，最後得到24個組合。以此為原種，製作成菌種，並於低海拔地區進行試種，大部份組合體均不能適應高溫下之生長，僅有 K53×D54（L107）可正常生長，且產量高，其特性為本菌株可以在高溫之低海拔下栽培，子實體形狀大，產量多，並可作為局部地區推廣及進一步育種之材料。本試驗證實什交育種可作為一種解決本省香菇品系來源之途徑，以得到適合本省栽培之高產優良品系。

本省生產之香菇在品質上，一般較日本生產者為差，此乃由於氣候、栽培管理及品種之差異所致(16)。因臺灣所栽培之香菇品種之原種，大部由日本引進，因此未能適合臺灣的栽培環境，致其產量及品質均不如日本者，幸而香菇屬於四極性之雌雄異體蕈類(6,17)，可利用什交育種加以改良其特性。又本省為香菇原產地之一，過去僅在高海拔地區可見香菇栽培，平地或低海拔栽培則未見報告，現正值農業型態改變之際，於是興起筆者嘗試平區或低海拔栽培研究之意念。要能在平地栽培，則必須在品系及栽培方式上加以改良，本省夏季溫度極高且維持時間亦長，必須找出可適合此種條件生長之品系，栽培技術上注意如何渡過高溫期，此可由栽培場降溫方式來克服(2)。又香菇為一種長期作物，若能以栽培方式如覆蓋及段木之加速成熟，則可縮短投資時間(5)，增加農民收益。香菇之育種方法一般有（１）單核菌絲之交配，（２）雙、單核菌絲之交配及（３）突變之利用。
Buller 現象之利用即屬於第二者，而取得單核菌絲之方法可由單胞子培養或由雙核菌絲經藥物處理而使之一核化(18,19,20)，唯後者較費時。因此若能取得一方之單核菌絲則可用 di-mon mating 法得到交配系統。Buller 現象先被廣泛應用於其他蕈類之研究(12,13,14)，但在香菇方面則以日本 Mori 氏(7)先得到具體之結果，他將日本野生香菇和臺灣及新幾內亞所採集之品系進行雙一單核之什交，發現彼此間可交換，亦同時證明香菇為四極性之交配。在臺灣，蘇氏(4)等由菌株之交配及子實體核數目之觀察，證實臺灣產香菇為典型四極性蕈類，且由交配過程中知單胞分離所得之菌絲不具扣子體（Clamp connection），但經由交配後部份菌絲能結合形成扣子體，部份只在接觸細胞處出現扣子體，有些菌株則全然無法形成扣子體(3)，藉此選擇出具扣子體之什交雙核體作為菌種材料。除上述方法外，有以癒合狀組織（callus-like tissue）作為接種源者，此法在液體及木屑培養基中均能產生多量子實體，可惜多為畸型，因此本方法有待進一步研究。經交配後之 F_1 後代雖亦會產生各種畸型子實體如不開傘，菌褶褐變，無孢子等，所幸其遺傳特性均由一因子所控制(9,10,11,12)，因此可由試種後而加以淘汰。基於以上之各種現象，筆者逐決定以 di-mon mating 法來進行臺灣香菇品系之育種，首先由臺灣採集野生品系，經過不同海拔試種，瞭解其特性，選取適合臺灣低海拔生育之品系

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，與日本野生及栽培品系進行什交，期能選出適合本省栽培之品系，本試驗則以低海拔段木栽培爲主，其他較高海拔及木屑栽培品系之育種仍需進一步試驗。

材料及方法

一、供試品系：本試驗所採用之品系包括本省野生香菇 5 種，日本野生香菇 4 種，日本栽培品種 6 種，共計15種，其來源及特性詳見表一。

表一、本試驗所使用品系之特性*

Table 1. Characteristics and source of 15 strains of *Lentinus edodes* in this study.

品系 Strain	子實體產生溫度 temperature for fruiting body formation	形態 shape of pileus	菌傘顏色 color of pileus	來源 Source	
D 54	15 ～ 28°C	中葉中肉	淡褐色	臺灣	新竹五峰
D 56	15 ～ 28°C	中葉中肉	淡褐色		新竹五峰
D 74	15 ～ 28°C	小葉中肉	淡褐色		南投松崗
D 191	15 ～ 24°C	中葉中肉	茶褐色		臺東卑南
D 223	15 ～ 24°C	大葉厚肉	淡褐色		南投蘆山
K 41	10 ～ 24°C	中葉中肉	深茶褐色	日本	東京都奥多摩
K 46	10 ～ 24°C	中葉中肉	淡茶褐色		北海道浦河町
K 53	10 ～ 24°C	大葉厚肉	深茶褐色		福島縣靈山町
K 60	15 ～ 28°C	大葉中肉	淡茶褐色		琦玉縣
森 465	10 ～ 24°C	大葉厚肉	明茶褐色	均爲日本栽培品種，由本省栽培所得之子實體經組織分離而得。	
森 701	10 ～ 25°C	大葉中肉	明茶褐色		
森 W4	12 ～ 25°C	中葉厚肉	明茶褐色		
北研58	15 ～ 25°C	中葉厚肉	濃茶褐色		
太陽	15 ～ 25°C	大葉厚肉	淡茶褐色		
大空	15 ～ 25°C	中葉厚肉	淡茶褐色		

*本表資料由參考文獻 1 及23整理而得。

*Data were summarized from references 1 and 23.

二、單胞菌絲之分離：由本省原生香菇栽培選拔試驗中 [1]，選取優良之香菇子實體，收集其胞子，並以稀釋平板法，在 PDA 培養基中，切取經發芽之單核菌絲（圖一及三），分別加以培養，並作單胞交配系（該部份將另文發表），由各交配型中選取數個菌株培養，再由此選出菌絲生長迅速之單核菌絲，保存於低溫石臘油中，供什交育種試驗用。

三、雙、單核菌絲之什交：雙核菌絲來源係由日本野生及栽培品系之子實體經組織分離而得，在 GMY 培養基（glucose 10g, malt extract 10g, yeast extract 4g, agar 18g, dist. water, 1 liter）進行雙、單核什交試驗，首先將單核菌絲移入 GMY 培養基之試管斜面或培養皿中央，在 24°C 培養，約兩星期後，在長滿菌絲之培養基上打直徑 5mm 之孔後將菌絲塊移出，並同時移入同一大小之雙核菌絲塊，然後繼續培養，經三星期後開始檢查單核菌絲之不同部位，並以

0.025%甲基藍 (methylene blue) 染色，檢查扣子體產生情形 (圖二) ，若產生扣子體則移入新的GMY 培養基中再予培養，供作菌絲生長速度及子實體產生能力等之測定。

四、什交雙核體菌絲生長速度測定：在以下之合成培養基中進行，培養基成份爲 glucose 30g, yeast extract 25g, malt extract 2.5g, KH_2PO_4 1.5g, $MgSO_4 \cdot 7H_2O$ 0.5g, $CaCl_2 \cdot 2H_2O$ 0.5g, agar 20g, DW. 1 liter. 將同一大小之前項所得之什交雙核體菌絲塊，移入裝有以上培養基之平板中央，分別置於 4 ，8 ，12，16，20，24，28，32，36及 40°C 培養，量取菌落直徑。

五、原基體 (primordia) 產生能力之測定：將各什交雙核體移殖於 PDA 培養基平板中央，分別在 12，16，20，24及 28°C 培養，並在一到二個月間不定期檢查其原基體產生情形。

六、木屑培養基之培養：以容量爲 500cc 之白色菌種玻璃瓶內裝木屑菌種培養基，將同一大小之什交雙核體菌絲塊移入，於 24°C 培養，在二個月內不定期檢查其菌絲生長速度及原基體產生情形，所使用之木屑菌種配方爲柯類木屑：楓香木屑：米糠：水 (12.5：12.5：8.3：66.7 (w/w)) ，並以碳酸鈣調節其 pH 值爲5.4。

七、各什交雙核體菌絲在低海拔地區之試種：選擇臺南縣官田鄉爲試種地區，該地區爲本省嘉南平原之一部份，海拔25公尺左右，夏季溫度高，但通風良好。由四、五、六項選出之菌絲生長良好，可在低溫下產生原基體及在木屑培養基上生長良好者24種，依常法作成木屑菌種後以楓香爲原木，按一般接種方法於三月接種，每菌株接種20支段木，每支段木長約 1 公尺，直徑約12公分，接種後並注意高溫什菌之防治，並以噴水方式處理使其出菇，調查段木存活及出菇情形，並以日本栽培品種森 465 作爲對照，該品系目前在本省栽培量最多且屬於較耐高溫之品系。

八、什交雙核體 L 107 (K53×D54) 在各地區試種情形：由前項試驗所得之優良菌株 L107 (K53×D 54) ，在高溫下可正常生長，且產量高，子實體正常，因此加以擴大栽培。首先將保存於低溫石臘油之該菌株，作成木屑菌種，再由菌種場繁殖後分送各地進行栽培試種，試種地區包括彰化縣埤頭鄉，臺南縣官田鄉，玉井鄉、楠西鄉，高雄縣六龜鄉，屏東縣枋寮鄉及屏東市。按香菇栽培要點及管理注意事項[2] 進行栽培，調查其產量及採收情形，並以森 465 爲對照，後者試種量爲 2 噸段木。

九、L 107 菌株之特性調查：於不同地區調查 L 107 菌株之特性，包括其生育情形，出菇溫度，子實體特性，乾燥後之品質、產量、病蟲害發生情形、栽培適合樹種、及管理要點，作爲日後栽培之依據。

結　　果

一、溫度對什交雙核體菌絲之生長及原基體形成之影響：由於同一品系之單胞菌絲生長差異極大 (圖四) ，所以從 5 種本省野生香菇子實體所得之各交配型之單胞菌絲中挑取生長迅速者各10個，經與雙核菌絲什交後得到 5 ×10×10個什交組合，在培養三星期到一個月間檢查其菌絲產生扣子體情形，經甲基藍染色後發現不同部位均可產生扣子體者 (圖五、六) 有 162 個組合，且其在菌絲分叉後亦可產生扣子體 (圖二) 。將這些組合在 4～40°C 培養，發現 4°C 時均無法生長，而 36°C 以上時均告死亡，最適合生長溫度爲 24°C 。選取在 24°C 時菌絲生長良好者 144 個菌株移殖於 PDA 平板中，在不同溫度培養，發現其中有24個組合在 16～24°C 可產生原基體，而以在 20°C 時產生者最多，其次爲 16°C, 24°C 時則較少 (表二) 。

二、什交雙核體在木屑培養基生長情形：以木屑代替洋菜培養菌絲時可瞭解其作成菌種後是否還能正常生長，亦即其是否適合作大量繁殖之用。由表三可知有些組合並不適合在木屑中生長，而形成原基體之能力差異大，且形成數量也不同，而有一種趨勢即可形成原基體之組合其菌絲往往生長良好，但菌絲生長良好者未必可形成原基體。

三、低海拔地區栽培試驗：由臺南縣官田鄉之試種情形可知在低海拔地區，因氣溫高，許多組合無法

表二、雙核什交體菌絲之不同溫度培養特性及原基體之形成

Table 2. Mycelium characteristics and primordium formation temperatures of di-mon F_1 isolates.

菌　株 Isolate	雙一單核什交體 di-mon mating	原基體產生溫度 primordium formation at			菌絲特性 mycelium characteristics
		24°C	20°C	16°C	
L 55	太 陽 ×D54 (2)*	−**	+**	−	平滑、白色、疏鬆
L 56	大 空 ×D56 (14)	+	+	−	平滑、白色、疏鬆
L 57	太 陽 ×D56 (33)	+	+	+	平滑、白色、疏鬆
L 58	森 W4 ×D54 (6)	−	+	−	平滑、白色、密緻
L 59	森 W4 ×D54 (8)	−	+	−	氣生、淡色、疏鬆
L 74	大 空 ×D74 (13)	−	+	+	平滑、白色、密緻
L 78	森 W4 ×D74 (13)	−	+	−	平滑、淡色、疏鬆
L 95	K 41 ×D54 (16)	−	+	−	平滑、淡色、疏鬆
L 96	K 41 ×D54 (8)	−	+	−	平滑、白色、疏鬆
L 102	K 46 ×D56 (3)	−	+	−	平滑、白色、密緻
L 107	K 53 ×D54 (26)	+	+	+	平滑、白色、密緻
L 109	K 53 ×D56 (13)	−	−	+	平滑、白色、密緻
L 112	北硏58 ×D54 (6)	−	+	−	平滑、白色、密緻
L 114	北硏58 ×D56 (6)	−	+	−	平滑、白色、密緻
L 134	K 60 ×D74 (6)	+	+	−	氣生、白色、疏鬆
L 191	大 空 ×D191 (7)	−	+	+	平滑、白色、密緻
L 195	森 W4 ×D191(12)	−	+	−	平滑、白色、密緻
L 276	K 53 ×D223 (1)	−	+	−	平滑、白色、密緻
L 283	K 60 ×D223(12)	−	+	−	平滑、白色、密緻
L 519	森 465 ×D54 (4)	−	−	+	氣生、淡色、疏鬆
L 521	森 465 ×D56 (14)	−	+	−	平滑、白色、疏鬆
L 539	森 465 ×D74 (2)	−	+	−	氣生、淡色、疏鬆
L 656	森 465 ×D191(12)	−	+	−	平滑、白色、密緻
L 775	森 701 ×D74 (2)	−	−	+	氣生 淡色 疏鬆

* ( ) 內數字表示由該品系子實體所得之單胞序號。
The number in the parenthesis is the single spore isolated from a fruiting body of each strain.

** ＋：表示原基體形成，－：表示無原基體形成。
＋: Primordium formed, －: non primordium formed.

表三、各什交組合體菌絲在木屑培養基之生長及產生原基體情形

Table 3. Mycelial growth and primordium formation of di-mon F_1 in sawdust medium.

菌株 Isolate	菌絲生長* mycelial growth	形成原基體** primordium formation
L 55	++	−
L 56	++	++
L 57	+++	+
L 58	+++	+
L 59	+++	++
L 74	+++	+++
L 78	+	−
L 95	+	−
L 96	++	−
L 102	+++	+
L 107	+++	+++
L 109	+	−
L 112	+	−
L 114	+++	++
L 134	++	−
L 191	+++	++
L 195	++	+++
L 276	++	−
L 283	++	−
L 519	++	−
L 521	+++	−
L 539	+	−
L 656	+++	++
L 775	+	−
對照 森465	+++	+

* 此爲在 24°C 下培養於木屑培養基四星期後之結果，菌絲伸展長度爲菌種瓶之$\frac{1}{4}$～$\frac{1}{2}$時以＋表示，$\frac{1}{2}$～$\frac{3}{4}$以＋＋表示，$\frac{3}{4}$以上以＋＋＋表示，未達$\frac{1}{4}$者以－表示。
mycelial growth : +++=fast>75% of length of spawn bottle ; ++=intermediate, 50—75%, + : slow, 25—50%, − : less than 25%.

** 原基體之成形以＋＋＋表示量多，＋＋表示中等，＋表示少量，－表示不產生。
primordium formation : +++=abundant, + +=intermediate, +=few, −=no formation.

適應而死亡，而有些則產生少量子實體，有些則產生不整型子實體，僅L 107 產生正常且量多之子實體，可作爲擴大栽培之用。而對照品系森465 則存活情形不良，且出現不整型子實體。而在

所有組合中有 7 個組合其所有栽培段木均告死亡（表四），比例極高。若與在海拔 400 公尺之埔里栽培之 K53 及 D54 子實體比較時，發現 L107 菌株之子實體其菌傘較大，傘肉較厚，其他

表四、各菌株在低海拔地區（臺南縣官田鄉）之栽培試驗

Table 4. Cultivation trial of di-mon F_1 isolates in logs of maple tree at Kuan-tien, Tainan. (25m from sea level)

菌株 Isolate	存活情形* survival (%)	出菇情形** fruiting body production
L 55	0	—
L 56	10	稀少，子實體圓形
L 57	55	稀少，子實體厚肉
L 58	20	—
L 59	15	多，不整型子實體
L 74	60	多，小型，顏色淡
L 78	0	—
L 95	30	—
L 96	30	稀少，子實體圓形
L 102	20	多，小型，顏色淡
L 107	95	多，子實體大型，正常
L 109	20	—
L 112	60	多，子實體小，不整型
L 114	20	—
L 134	40	稀少，不整型
L 191	30	多，子實體小，圓型
L 195	10	—
L 276	0	—
L 283	0	—
L 519	0	—
L 521	0	—
L 539	0	—
L 656	4	少，子實體，不整型
L 775	10	—
對照 森 465	20	少，子實體小，不整型

* 表列數字表示每20支段木經培養一年後之存活百分比。
Survival percentages were based on 20 logs one year after incubation.

** 出菇操作於71年 8 月到72年 4 月間進行，共處理五次。
Fruiting bodies were harvested from August 1982 to April 1983 in 5 times of treatments for fruiting.

性狀差異不大（表五），但可適應低海拔地區栽培之特性則不同。

表五、K53×D54什交組合體與K53及D54之子實體特性比較*

Table 5. Comparison on the characteristics of fruiting bodies of K53, D54 and their di-mon F_1 K53×D54.

特性 Characteristics \ 菌株 Isolate		K 53	D 54	K53×D54 (L 107)
菌傘大小 (cm)	diameter of pileus	7.4	6.5	8.3
厚度 (cm)	thickness of pileus	1.2	1.0	1.5
毛茸	hairs	無	無	無
色澤	color of pileus	深茶褐色	淡褐色	茶褐色
鱗片	scales	中等	小	中等
菌褶間距 (個/cm)	distance among the gills (individual/cm)	18	18	20
菌柄長度 (cm)	length of stalk	5.0	3.0	4.5
直徑 (cm)	diameter of stalk	2.0	1.2	2.0
鮮重 (g)	fresh weight	19	19	25
乾重 (g)	dry weight	4.5	4.4	5.2
菇體成長所需日數	days for maturity of fruiting bodies	5	5	5
出菇數目 (朶／100孔)	No. of fruiting body (individual/100 pores)	115	109	120
菇距	distance among fruiting bodies	5.5	7.5	7.0
平均乾燥率	average ratio of drying	1：4	1：5	1：5

* 各數字爲100朶八分開子實體之平均結果。

Data were based on the average of one hundred of eight parts opened fruiting bodies.

四、什交雙核體 L107 (K53×D54) 在各地栽培試驗：由不同地區之栽培結果可知當 L107 菌株在本省中、南部栽培時極爲適合，且由海拔10至 250公尺均能生長，栽培樹種則包括楓香、校栗、皂斗、薯豆、柯類、土生樣果等，第一年收穫乾量即佔段木重量之 0.50～0.83 %，而對照品系森465僅佔0.21%，而且 L107之子實體可正常生長，採收期則可由八月到翌年三月，預計總收量可達段木重量之 2～3 % (表六)。

五、L 107 菌株之特性：由表七可知其主要特性爲菌絲生長快（圖七），在培養基平板（圖八）及木屑中均可產生原基體，適合低海拔地區之栽培（圖九），出菇期間長，菇形略爲扁平，菌傘顏色

表六、L 107菌株在各地之段木試種情形*

Table 6. Cultivation trials of L107 isolate at different location in Taiwan

栽培地點 Place	當地海拔 elevation (meter)	栽培樹種 kinds of logs	栽培數量(噸) amount (tons)	第一年乾燥產量(公斤) dry yield of first year (kg)	產量比(乾重/段木重) ratio of yield (dry yield of fruiting bodies /wt. of log)	採收期間及次數 period and times of harvest	出菇操作 Fruiting method
彰化縣 埤頭鄉 Changhua Hsien Pei-tou	10	楓香、校栗、柯類、薯豆	70	500	0.70%	72年8月至73年2月，8次	噴水
臺南縣 官田鄉 Tainan Hsien Kuan-tien	25	楓香、柯類、皂斗	40	330	0.83%	72年10月至73年2月，5次	噴水
臺南縣 玉井鄉 Tainan Hsien Yu-Jeng	60	檬果、楓香、薯豆、柯類	60	300	0.50%	72年10月至73年2月，5次	噴水
臺南縣 楠西鄉 Tainan Hsien Nan-si	150	楓香、校栗、柯類、薯豆	65	500	0.77%	72年11月至73年2月，5次	噴水
高雄縣 六龜鄉 Kaohsiung Hsien Leio-kuei	250	楓香、柯類、校栗	35	192	0.60%	72年10月至73年3月，6次	噴水
屏東縣 枋寮鄉 Pingtung Hsien Fang-liao	10	楓香、柯類、薯豆	17	90	0.53%	72年10月至73年2月，6次	噴水
屏東市 Ping-tung City	15	楓香、薯豆、皂斗	45	320	0.70%	72年6月至73年2月，5次	噴水

* 對照品系為森465，每處栽培2噸段木，僅於楠西鄉及官田鄉各收穫4公斤及4.2公斤，其他地區則告死亡。
The check strain Mori-465 were dead, only 4 kg and 4.2kg of fruiting bodies were harvested at Nan-si and Kuan-tien, Tainan.

為深褐色到淡褐色，大部份香菇栽培樹種均能適應生長，接種後若注意水份及溫度之調節則極易

表七、L 107 菌株之特性表

Table 7. The characteristics of isolate L107

項目 Item		主要特性 main characteristics	
菌絲培養	Mycelial growth	1.在PDA平板上	菌絲生長旺盛，平均，爲白色密緻。
		2.在木屑中	生長快，極易形成原基體。
		3.在低溫下	在 16～24°C 下可形成原基體。
出菇適溫	temperature for fruiting	1.在低海拔（250～100公尺）	15～24°C
		2.在平地（海拔100公尺以下）	15～28°C
出菇期間	fruiting period	主要在10月至翌年4月，但6～9月仍可出菇。	
菇體特性	characteristics of fruiting bodies	菇體在高溫下呈淡褐色，傘肉較薄，在 15～20°C 下則爲厚肉茶褐色，大葉，柄中等，菌褶密生，周邊有鱗片，在高濕下顏色可變爲深褐色。著生較密時，貼近段木，傘易受段木阻礙而呈偏生。	
乾燥特性	characteristics after drying	乾燥後菇體呈扁平，暗褐色～暗黑色，菌褶淡黃色，具光澤，乾燥比在 1：5～6。	
產量	yield	以楓木栽培時乾燥產量在段木重量之2.5～3.0%，以10～12月產量最多。	
病害發生情形	disease occured	病害發生在初期以綠黴菌爲主，應注意預防，次爲栽培期中之黏菌，避免使用黃槿作爲原木可減少該病之發生，只要不使香菇菌絲死亡則病害易控制。	
適合栽培樹種	kinds of logs for cultivation	以楓香、柯類、、薯豆、土生橡果、校栗、石櫧、皂斗爲主，避免使用黃槿、紅九層作爲原木。	
管理要點	points of management	1.接種後注意濕度之保持，栽培場相對濕度維持在75～80%。 2.接種後注意栽培場溫度控制在 28°C 以下，尤其夏季。 3.段木適時予以補充水份。 4.栽培場高度應在4公尺以上，且東、西向應以竹籬遮陰。 5.以噴水或浸水處理均可，噴水以二天二夜，浸水以不超過18小時爲宜。 6.處理次數以每年4～6次爲宜。	

栽培。

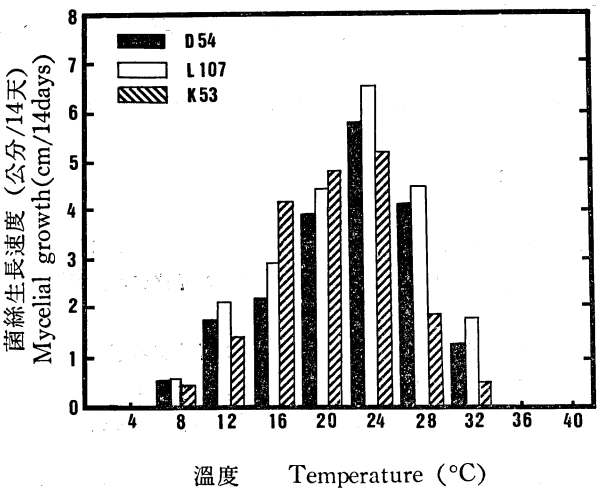
討　論

目前本省香菇段木栽培地點均在海拔 400 公尺以上的山地或山坡地，過去曾有許多人以日本品系作低海拔地區之試種，但均未能成功，又日本品系中之森 465 爲本省栽培量較多之品系，但在低海拔

下生育情形亦不理想（表四）。在木屑栽培方面，本省由於品系未能穩定，致在栽培上常造成失敗，因此本試驗仍以段木栽培爲主，但有時候適合段木栽培之品系並不一定可適合木屑栽培，反之亦然。

Buller 現象之應用在 Mori 氏得到良好效果後，應用於香菇育種方面甚爲普遍，由於核的移動，在不同來源之控制因子之影響下，極易交配，且可由扣子體的形成檢視其是否完全融合，使得香菇育種工作較容易進行。時本氏[21]等指出在夏天可出菇者其菌絲在 25°C 下培養亦可產生原基體，而在較低溫度出菇者，則往往必須在 20°C 下培養才會形成原基體。本試驗之菌株 L107 在16，20及24°C 下均可產生原基體，且可在夏天出菇，與其結果相符。Tokimoto 氏[8]提在到洋菜培養基上可產生具菌傘、擔子器、擔孢子等之塊狀不完全子實體者，在段木上則不一定可以出菇，本試驗表二及表四之結果顯示許多可產生原基體之菌株在段木栽培時雖未死亡，但亦不會出菇，亦與 Tokimoto 之報告相符。雖然過去學者對使雙核產生一核化的研究很多，但未若胞子稀釋平板法來得簡便，前者在未能得到單核菌絲時有效，但若可得到任何一種單胞則不需經一核化的過程。

在栽培特性上，可見 L 107 菌株與 K53 或 D54 品系，在菌傘直徑，菌柄長度，菌傘厚度，菌柄直徑，菌傘顏色及乾燥率上有所不同，野生品系 K53，具適合較高海拔及子實體形狀良好之特性，但在低海拔則無法生存，野生品系 D54 菇形較差，顏色淡，傘肉薄，但具有適合本省高溫生長之特性（圖十及十一），因此什交體 L 107（K53×D54）兼具菇形大，及適合高溫生長之特性，一般而言顏色比 D 54 爲深，只有在夏季栽培時顏色略爲變淡。由圖十二可知，三者菌絲生長最適溫度爲



圖十二、溫度對 K 53, D54及L 107 等三個香菇菌絲生長之影響

Fig. 12. Effect of temperature on the mycelial growth of K53 (▨) D54 (■) and L107 (□).

24°C，當達到 36°C 時均告死亡，在 28°C 時 L107 菌株仍可生長良好，K53 品系則較差。又在所有試種之 L 107 菌株之子實體中亦未發現有如小松氏[9,10,11]所稱之菌傘褐變，不開傘或無胞子現象出現。

在低海拔時，夏季氣溫往往超過 30°C，頗不適合香菇菌絲之生長，因此非有耐熱之品系無法得到良好栽培結果，而本菌株（L 107）在各地試種情形來看，極適合一般低海拔之栽培，而且對於樹種之適應性亦大，一般香菇栽培樹種均能適應，且子實體生長正常，採收期亦長。第一年採收量佔段木重量之0.50～0.83%，已經接近成本。繼續採收預計產量可達段木重量之 2～3 %。

本試驗得到適合低海拔栽培之品系，且產量高，打破過去平地段木栽培不可能的說法。在目前稻田轉作聲中，香菇作地區性的栽培應屬可行，只要品質及特性再加改良，或以 L 107菌株再與其他優

良品系作什交育種，必可育出更優良的品系，適合一般平地栽培，在創造農村財富，改造農村新面貌中，香菇栽培也可擔任一重要之角色。

誌　謝：

本試驗所採用之臺灣野生香菇品系，係民國六十四年開始由臺大、興大、農試所等單位合作辦理採集工作，並由農試所主辦，本所前植病系主任杜金池博士主持、杜自疆先生協助。再於民國六十八年起由農試所與臺大鄭燓教授、興大韓又新教授合作野生香菇不同地區之試種，本試驗則由農試所在埔里、魚池地區所試種而得之適合低海拔生長之野生品系中選出五種品系作爲育種材料，爲求本文資料之完整，特向以上諸位先生致謝。

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Studies on the Breeding of Shiitake—a New Strain for the Cultivation in the Low Elevation Areas[1]

Ying-ming Liao[2]

Summary

In this study, five strains of *Lentinus edodes* from Taiwan, 4 wild strains and 6 cultivated strains from Japan were used in the di-mon mating method to breed a new strain for the cultivation in the low elevation areas in Taiwan. Ten single spore isolated each of the five wild strains from Taiwan were used as monokaryons and both wild and cultivated strains from Japan were used as dikaryons which resulted in 500 all possible crosses, isolates or di-mon matings. Twenty-four out of the 500 isolates produced primo rdia on agar medium with a strong vigor of mycelial growth. The cultivation trails of the 24 isolates at Kuan-tien (25m from sea level) indicated that the isolate L107 (K53×D54) was very promising because it produced an economic yield and the shape and size of its fruiting bodies were normal and large. From the large scale trials on different kinds of logs at different locations in the areas of less than 250m from sea level, isolate L107 produced economic yield and the quality of the fruiting bodies is also good. Therefore, it can be either cultivated in the low elevation areas in Taiwan, or used as a breeding material for further improvement.

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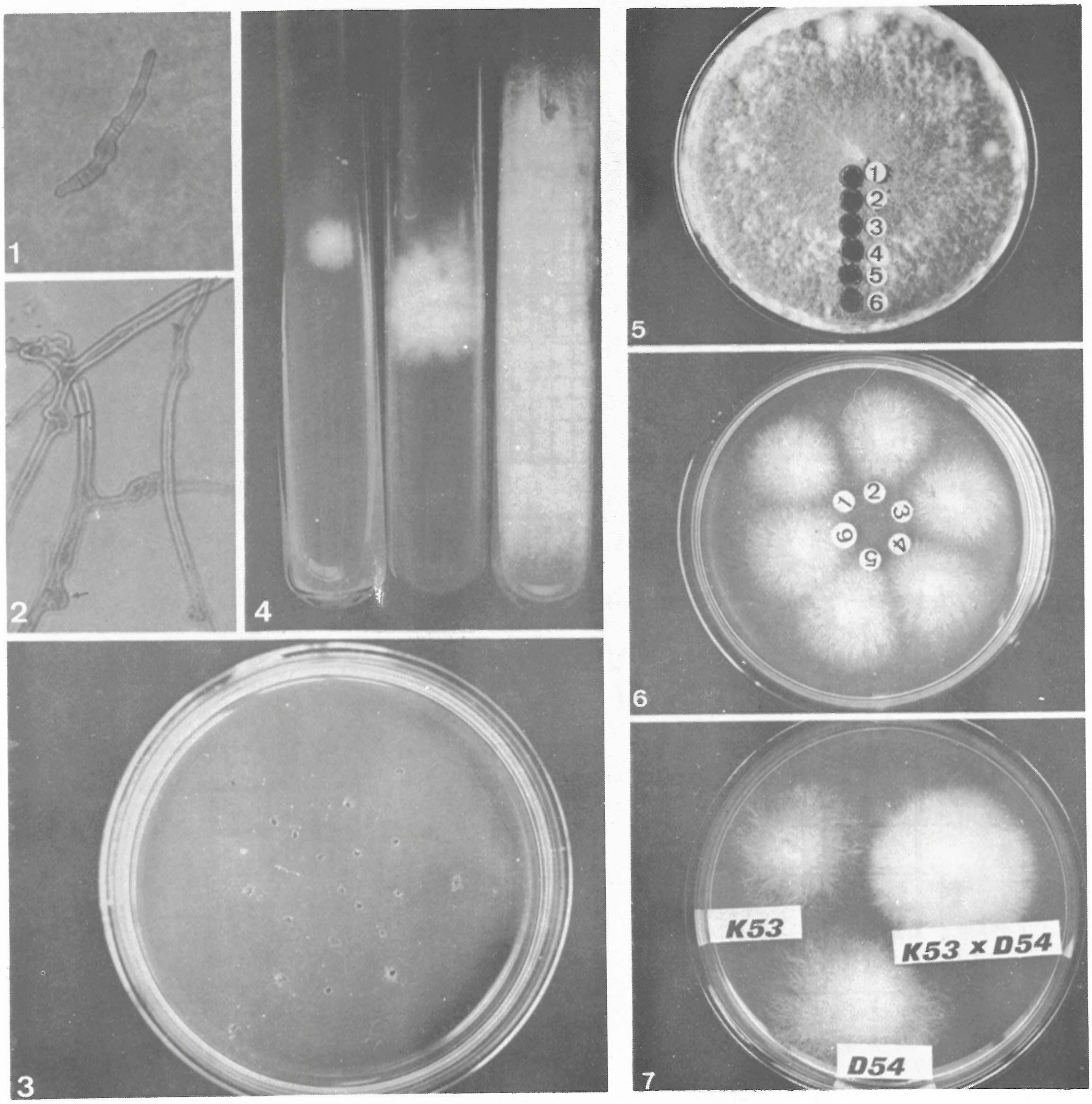

圖 一、香菇單胞發芽情形

Fig. 1. The germination of single spore from a fruiting body of *Lentinus edodes.*

圖 二、雙一單核菌絲雜交後形成扣子體（箭頭部份）。

Fig. 2. The clamp connections formed in a di-mon mating (arrows pointed) .

圖 三、由培養基平板挑取已經發芽之單胞

Fig. 3. Agar plate after the removal of germinated single spores.

圖 四、單胞菌絲生長速度差異極大

Fig. 4. Differences of mycelial growth among single spore isolates.

圖 五、檢查不同部位之雙一單核雜交菌絲

Fig. 5. Investigation of clamp connection formed at different distances of a di-mon · mating mycelia.

圖 六、不同部位之雙一單核雜交菌絲經培養後均可產生扣子體

Fig. 6. Clamp connections were observed in all di-mon F_1 mycelia cut from different distance.

圖 七、雜交組合K53×D54與K53、D54之菌絲生長比較

Fig. 7. Comparison on the mycelial growth of K53×D54, K53 and D54 isolates.

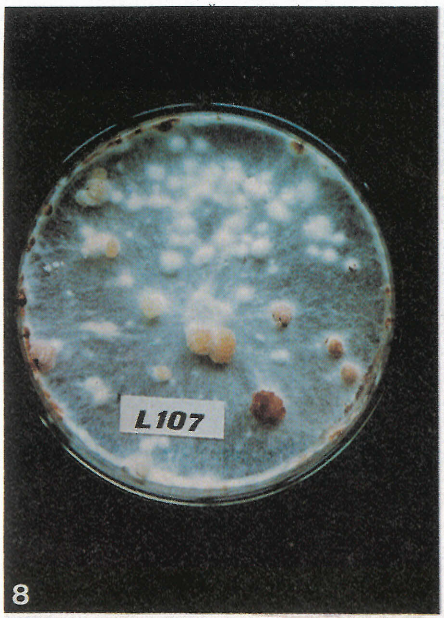

圖 八、L107菌株培養於PDA平板產生原基體或癒合狀組織之情形

Fig. 8. The primordia or callus-like tissues of L107 isolate formed on a PDA agar plate.

圖 九、L107菌株子實體在楓香段木之著生（栽培於海拔150公尺）

Fig. 9. The formation of fruiting bodies of isolate L 107 on the logs of maple trees (cultivated at 150 m from sea level).

圖 十、D54菌系子實體在段木之著生情形（栽培於海拔400公尺）

Fig. 10. The fruiting bodies of strain D54 growing on the log (cultivated at 400 m from sea level).

圖十一、K53菌系子實體在段木之著生情形（栽培於海拔 400 公尺）

Fig. 11. The fruiting bodies of strain K53 growing on the log (cultivated at 400 m from sea level).

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玉米銹病判別與抗病篩選[1]

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摘要：本試驗之目的，(1)提供本省兩種玉米銹病之鑑別方法，(2)提供篩選方法並測定玉米品系對銹病之抵抗性做爲育種之指標。本省玉米有普通型及南方型兩種銹病，普通型其夏胞子堆之病斑爲卵圓形到細長形，咖啡色，並常附有寄主表皮，多胞子堆黑褐色到黑色，開敞狀，爲夏胞子堆轉換而成，夏胞子黃褐色，近乎圓形，多胞子咖啡色到黑褐色，周圍圓滑，頂端明顯加厚。南方型其夏胞子堆時期之病斑爲小圓形，金黃色，多胞子堆黑褐色到黑色，散生在夏胞子堆周圍，被植物表皮覆蓋的時間較長，夏胞子金黃色，卵圓形，多胞子黃褐色，常呈稜角狀，頂端部分加厚不明顯。先用離葉法培養接種源，然後四至六葉之玉米幼苗以夏胞子懸浮液接種，經過六至十天後記載病斑形態，無可見病徵到退綠色黃斑者爲抗病型，黑色壞死小點到小形夏胞子堆者爲中抗型，夏胞子堆完全發育並大量產胞者爲感病型，共測定 984個品系，抗普通型銹病者有臺農育351號及351母本改良系等多品系，抗南方型銹病者較少，初步試驗結果只有 ER172, ER318, ER325及 ER504 等抗性較强，臺南五號及臺南十一號對此兩種銹病均無抵抗性。

玉米銹病根據文獻之記載有三種，分別爲 *Puccinia sorghi* Schw. 引起之普通型銹病（common maize rust), *P. polysora* Underw. 引起之南方型銹病（southern rust）及 *Physopella zeae*（Mains) Cummins and Ramachar 引起之熱帶型銹病（tropical rust）[11,12,15]。本省過去有關玉米銹病之研究甚少，孫氏等[1]在1976年報告本省所發生者主要爲普通型，南方型爲當時新發現之病害，近年來由於玉米栽培時期及栽培品種之改變，南方型顯得比普通型重要，孫氏等之報告因爲沒有圖片及詳細說明，致使一般人要區別此兩種銹病發生困難。

玉米銹病最經濟而且有效之防治方法爲採用抗病品種，美國大都採用此法[15]，甚至在抵抗性遺傳方面也已經有深入之研究[2,3,6-9]，而本省玉米之抗銹病育種，過去因爲沒有病理人員配合，所以育成之品種缺乏抵抗性，1983年東部之玉米南方型銹病發生嚴重即爲證明。

本試驗之目的，(一)提供區別兩種玉米銹病之方法使一般人得以辨認，(二)配合育種計畫，測定本所現有種源及分離培育之材料對兩種銹病之抵抗性，選出抗病材料供育種之用。

材料與方法

一、銹病之鑑別：玉米生長季節，不定期到田間調查銹病發生情形，採集銹病標本，仔細觀察並記載其特徵，比照參考文獻[15]內所描述之病徵與圖片說明，鑑定銹病之種類，低溫季節，注意是否有黑色之多胞子堆形成，不同之病徵除拍照以便比對外，多胞子及夏胞子時期並做切片在顯微鏡下觀察記錄，並拍照片以便比較其異同。

二、抗病篩選：

1.病菌之培養——採用 Hooker 氏[7]之離葉法（detached leaf method），但經過改良，先於

1.臺灣省農業試驗所　研究報告第 1170 號。本研究承農發會補助（73農建—2.1—產—125），抗病篩選之材料由農藝系呂副研究員宗佳等提供，試驗工作承李應岳先生及陳芬蘭小姐協助，併此致謝。
2.本所植病系副研究員。臺灣省　臺中縣　霧峰鄉。

直徑9公分經過消毒之培養皿內放一薄層棉花,上面再加一層濾紙,然後以蒸餾水加蔗糖(5%,v/w)及 Kinetin(20ppm)之溶液潤濕備用。溫室栽培六至八週之感病品種超甜玉米 236號或飼料用玉米臺南五號之新鮮葉片,剪成長度約七公分之片段,以自來水洗去表面之塵垢,並以乾淨之濾紙或衛生紙吸去表面多餘之水份後,置於前述準備好之培養皿內,葉片之上表皮向上。從田間所採得之病葉,選擇只有一種銹病感染且其夏胞子較新鮮者,以含展着劑(Tween 80, 100ppm)之無菌蒸餾水製成胞子懸浮液,其濃度約爲二萬個胞子/ml,最後再以軟毛毛筆沾此胞子懸浮液均勻塗抹在上述培養皿內之葉片上,在室溫(24—28°C)經過二週後即會有新的夏胞子堆產生,反覆進行此法以繁殖夏胞子,到有足量之夏胞子供溫室內抗病篩選時接種之用爲止,若在田間行大面積接種,則接種源採自田間新鮮病葉。

2.抗病測定:

(A)供試材料——包括本地種及本所現有之種源及分離培育之材料共984種品系,其中簡稱 ER 者有356種係源自美國夏威夷大學之 F_4 世代之早期分離自交系統,簡稱 SW 者有203種係源自泰國 Suwan-1 Thai Composite No. 1 DMR 之品系,簡稱 PI 者有333種,源自美國 Pioneer 種子公司之 PI 6875 之 F_4 世代,簡稱 IMP 者有81種,爲本所育成之臺農育351號之母本(TA 80-2598)改良系,本所分離及培育者計有臺農育351號、臺農365號、臺農 121號、新1號、新2號、新3號、351父本、351母本及365母本等9種,本地種有臺南五號及十一號。

(B)測定方法——以幼苗法行之,普通型銹病第一次試驗在田間進行,每個品系一米長種20株,株距5公分,品系間之行距約60公分,當玉米在四至六個展開葉片時,利用採自田間之新鮮夏胞子依上述之方法製成懸浮液,於傍晚時分以背囊式噴霧器行噴霧接種,然後試驗區灌水以提高濕度,並以透明塑膠布覆蓋植物,使葉片表面有游離水份有利於病菌之發芽與侵入,次日(經過16至24小時後)移去塑膠布使其自然發病,經過二至三週後調查並記載每個品系上之病斑形態,由於在田間進行需要大量接種源又氣溫升高,以後之試驗均改在環境因子比較容易控制之溫室或生長箱內進行。試驗時以長10公分寬15公分之塑膠袋裝土後種植供試品系,每品系一袋每袋三株,當玉米在四至六個展開葉片時用實驗室培養之接種源以噴油漆之噴霧器行噴霧接種,然後植株亦覆蓋塑膠布,保濕16至24小時後取去,經過6至10天後調查並記載病斑之大小等級,普通型銹病篩選時外界之溫度應在 20° 至 26°C 之間,南方型銹病篩選時外界之溫度應在 24° 至 30°C之間,若溫室內之氣溫不在上述範圍則試驗改在生長箱內進行。本試驗所採用之病斑等級係綜合 Scheiber 氏[14]與 Storey 及 Howland 氏[16]等之方法而成,R 爲抵抗型,表示無肉眼可見之病徵或爲退綠色之黃斑;M爲中抗型,表示出現黑色壞死小點到小型夏胞子堆;S 爲感病型,表示夏胞子堆完全發育並大量產胞者。第一次篩選時所獲得之抗病或中抗品系及未發芽者進行第二次篩選試驗,以此類推,試驗次數依種子之數目而定。

結　果

一、玉米銹病之鑑別——本省玉米上的兩種銹病,可用肉眼依其病徵或在顯微鏡依夏胞子及多胞子之形態來區別,普通型銹病,其夏胞子堆時期之病斑爲卵圓形到細長形,咖啡色,並常附有寄主表皮(圖一),多胞子堆黑褐色到黑色,呈開敞狀,爲夏胞子堆轉換而成(圖二),夏胞子黃褐色,近乎圓形(圖三),多胞子咖啡色到黑褐色,周圍圓滑,頂端明顯加厚(圖四)。南方型銹病其夏胞子堆時期之病斑爲小圓形,金黃色(圖五),多胞子堆黑褐色到黑色,散生在夏胞子堆周圍,而且被植物表皮所覆蓋的時間較長,所以多呈密閉而非開敞狀(圖六),夏胞子金黃色,卵圓形(圖七),多

胞子黃褐色，常呈稜角狀，頂端部分加厚不明顯（圖八）。

二、抗普通型銹病篩選——源自夏威夷大學之種源，其試驗在田間進行，356個供試品系中有119個表現抗病型（表一）。源自泰國之種源，經過溫室內四次選汰試驗， 203個供試品系中四次都表現抗病型者有 SW 574 及 SW 573 等二種，三次表現抗病型者有 SW 548 等七種，二次表現抗病型者有 SW 558 等三十七種，一次表現抗病型者有 SW 552 等四十七種（表二）。源自美國Pioneer

表1. 玉米 ER 種源抗普通型銹病篩選[a]

Table 1. Screening of maize ER germplasm for resistance to common rust (*Puccinia sorghi*)[a]

篩選數目 (Accessions screened)	銹病反應 (Rust reaction)[b]		
	R	M	S
356	119[c]	0	237

a 試驗在農試所21號田進行，播種—73.2.21，接種—73.3.20，調查—73.4.5，(Experiment was conducted in the experimental farm of TARI ; sown-2, 21, 1984 ; inoculated-3, 20, 1984 ; read-4, 5, 1984).

b R—抗病型 (resistant) 無肉眼可見之病徵或退綠色黃斑 (no visible symptom or chlorotic spots).
M—中抗型 (moderate) ，黑色小點到小形夏胞子堆 (necrotic flecks, or with medium size, not fully developed uredia)
S —感病型 (susceptible) ，夏胞子堆完全發育並且大量產孢 (fully developed uredia which sporulated abundantly)

c ER 10, 11, 15, 16, 19, 27, 30, 45, 47, 56, 61, 62, 64, 66, 72, 73, 77—80, 86, 89, 91, 95, 96, 99, 105, 108, 109, 111—113, 116—119, 121, 124, 130, 132, 133, 135, 138, 139, 140, 143, 144, 148, 150, 155, 158, 159, 162—164, 166, 167, 171, 179, 183, 187, 200, 213—215, 217—220, 223, 225, 228, 233, 236, 238, 242, 244, 251, 253, 261, 263, 265, 283, 287, 297, 310, 312, 314, 318, 320, 325, 326, 327, 329, 333, 334, 343, 344, 349, 352, 353, 355, 366, 373, 383, 385, 386, 388, 397, 407, 409, 411, 423, 430, 464, 469, 524, 536, 635

表2. 玉米 SW 種源抗普通型銹病篩選[a]

Table 2. Screening of maize SW germplasm for resistance to common rust (*P. sorghi*)[a]

試驗次別 (Expt. No.)	篩選數目 (Accessions screened)	銹病反應 (Rust reaction)[f]		
		R	M	S
1[b]	203	85	19	99
1[c]	104	60	27	17
3[d]	87	18	56	13
4[e]	18	9	6	3

a 試驗在溫室進行 (Experiments were conducted in the greenhouse)

b 播種—73.3.23，接種—73.4.5，調查—73. 4. 16， (sown-3.23. 1984 ; inoculated-4.5, 1984 ; read-4.16, 1984)

c 播種—73.4.17， 接種—73.4.28，調查—73.5.8， (sown-4.17, 1984 ; inoculated-4.28, 1984 ; read-5.8, 1984)

d 播種—73.5.9，接種—73.5.17，調查—73.5.25， (sown-5.9, 1984 ; inoculated-5.17, 1984 ; read-5.25, 1984)

e 播種—73.5.26，接種—73.6.5，調查—73.6.13， (sown-5.26, 1984 ; inoculated-73.6.5 ; read-73.6.13)

f R 抵抗型 (resistant), M 中抗型 (moderate), S 感病型 (susceptible)

*四次試驗都表現抗病型反應者—SW 574, 734.

**三次抗病型反應者—SW548, 598, 616, 649, 651, 683, 732,

***二次表現抗病型反應者—SW558, 561, 565, 570, 573, 577, 580, 584, 588, 585, 593, 599, 607, 609, 614, 629, 633, 643, 654, 655, 657, 665, 666, 694, 684, 687, 695, 699, 701, 703, 704, 711, 716, 725, 730, 742, 747.

****一次表現抗病型反應者—SW 552—556, 559, 560, 576, 579, 590—592, 601, 602, 604—606, 618, 619, 621, 625, 627, 630, 638, 644, 648, 652, 670, 680, 681, 688, 691, 693, 702, 705, 707, 713, 718, 720, 721, 728, 731, 733, 735, 740, 743, 744,

種子公司之種源共有333個品系，絕大多數均爲感病型，第一次試驗只發現 PI 325 及 PI 486 爲抵抗型，但經過第二次試驗後，只發現 PI 540具有中等抵抗性（表三），本所育種材料之351母本改良

表3. 玉米 PI 種源抗普通型銹病篩選[a]

Table 3. Screening of maize PI germplasm for resistance to common rust (*P. sorghi*)[a]

試驗次別 (Expt. No.)	篩選數目 (Accessions screened)	銹病反應 (Rust reaction)[d]		
		R	S	M
1[b]	333	2[e]	6[f]	325
2[c]	8	0	1[g]	7

a 試驗在溫室內進行 (Experiments were conducted in the greenhouse)
b 播種—73.5.15；接種—73.5.25；調查—73.6.1；(sown-5.15.1984；inoculated-5.25.1984；read-6.1.1984)
c 播種—73.5.26，接種—73.6.22，調查—73.6.30 (sown-5.26.1984, inoculated-6.22.1984, read-6.30.1984)
d R—抵抗型 (resistant), M—中抗型 (moderate), S—感病型 (susceptible)
e PI 325, 486
f PI 297, 438, 506, 526, 527, 540
g PI 540

系，大多數爲抗病型，第一次試驗共測定81個品系，但有 7 個未發芽，在74個品系中即有58個爲抗病型，再經過第二次試驗，仍有49個表現抗病型反應，而且在兩次試驗中都表現抗病型反應者有IMP 6 等四十三種，一次表現抗病型另一次表現中抗型者有 IMP 2 等四種，一次表現抗病型一次爲感病型者有 IMP 8 等八種（表四），本所分離培育之材料及本地種，在每次試驗中均有測定，做爲對照品

表4. 玉米351母本改良系 (IMP) 抗普通型銹病篩選[a]

Table 4. Screening of IMP breeding materials for resistance to common rust (*P. sorghi*)[a]

試驗次別 (Expt. No.)	篩選數目 (Accessions screened)	銹病反應 (Rust reaction)		
		R	S	M
1[a]	74	58	0	16
2[b]	62	49	4	9

a 試驗在溫室進行 (Experiments were conducted in the greenhouse)
b 播種—73.5.17；接種—73.5.25，調查—73.6.1 (sown-5.17.1984, inoculated- 5.25.1984, read-6.1.1984)
c 播種—73.6.2，接種—73.6.22，調查—73.6.30 (sown-6.2.1984, inoculated-6.22.1984, read-3.30.1984)
*二次試驗均表現抗病型反應者—IMP 6, 7, 9, 15—24, 29, 35—43, 45, 48, 50—53, 56, 58, 60, 61, 66, 68, 70, 71, 74, 76, 80, 81, 90.
**一次表現抗病型一次爲中抗型反應者—IMP 2, 3, 75, 84.
***一次表現抗病型一次感病型反應者—IMP 8, 12, 26, 27, 44, 47 , 59, 62, 77, 78, 87

種，綜合多次試驗結果，發現臺農育351號，臺農365號、351號父本及365號父本對普通型銹病有很强之抵抗性，其中臺農育 351號與實際在農民玉米田觀察之反應相同，均爲抗病型（作者尚未發表之結果），臺農育351號之母本、臺農121號、新 1 號、新 2 號、新 3 號、臺南 5 號及臺南11號等對普通型銹均無抵抗性（表五）。

表5. 農試所育成之品種及育種材料與栽培種對普通型銹病抵抗性之比較

Table 5. comparison of resistance to common rust between cultivar and/or breeding lines of TARI and commercial caltivars.

來 源 (Source)	品 種(系) 名 稱 (Cultivar/line)	銹 病 反 應[a] (Rust reaction)
農 試 所	臺 農 育 351 號	R
	臺 農 365 號	R
	351 父 本	R
	365 父 本	R
	351 母 本	S
	臺 農 121 號	S
	新 1 號	S
	新 2 號	S
	新 3 號	S
一 般 栽 培 種	臺 南 5 號	S
	臺 南 11 號	S

a R—抵抗型 (resistant)；S—感病型 (susceptible)

三、抗南方型銹病篩選——源自夏威夷大學之種源，因種子有限，故對南方型銹病抗性測定只試驗一次，供試183個品系中只發現ER172, ER318, ER325 及 ER504 等爲抗病型，ER582 爲中抗型，其中ER318 及 ER 325 同時兼抗普通型銹病（表六）。源自泰國之材料對南方型銹病之抗性不强

表6. 玉米 ER 種源抗南方型銹病篩選[a]

Table 6. Screening of maize ER germplasm for resistance to southern rust (*Puccinia polysora*)[a]

篩 選 數 目 (Accessions screened)	銹 病 反 應 (Rust reaction)[b]		
	R	M	S
183	4[c]	1[d]	178

a 試驗在溫室進行，播種—73.4.18，接種—73.4.30，調查—73.5.8，(Experiment was conducted in the greenhouse, sown-4.18.1984, inoculated-4.30, 1984, read-5.8, 1984).

b R—抵抗型 (resistant), M—中抗型 (moderate), S—感病型 (susceptible)

c ER 172, 318, 325, 504

d ER 582.

，經過三次試驗只有 SW581 及 SW721 在第一次表現抗病型，但它們在以後之試驗中即表現中抗型，SW561 及 SW627 在三次試驗中均表現中抗型反應（表七）。源自 Pioneer 公司之種源及351母本改良系等之材料，對南方型銹病均缺乏優良之抵抗性，只有極少數品系具中等抗性（表八，表九），本所分離培育之材料與本地種共有臺農351號、臺農 365號、臺農121號、新 1 號、新 2 號、新 3 號、351父本，365父本，351母本及臺南 5 號、臺南11號等均極感病。

表7. 玉米 SW 種源抗南方型銹病篩選[a]

Table 7. Screening of maize SW germplasm for resistance to southern rust (*P. polysora*)[a]

試驗次別 (Expt. No.)	篩選數目 (Accessions sereened)	銹病反應 (Rust reaction)[b]		
		R	M	S
1[c]	202	2[f]	2[g]	198
2[d]	5	0	3[h]	2
3[e]	4	0	3[i]	1

a 試驗在溫室內進行 (Experiments were conducted in the greenhouse)

b R—抵抗型 (resistant), M—中抗型 (moderate), S—感病型 (susceptible)

c 播種—73.4.18，接種—73.4.28，調查—73.5.8，(sown-4.18 1984, inoculated-4.28, 1984, read-5.8 1984)

d 播種—73.5.9，接種—73.5.17，調查—73.5.28，(sown-5.9 1984, inoculated-5.17 1984, read—5.28 1984)

e 播種—73.6.12，接種—73.6.22，調查—73.7.2，(sown-6.12 1984, inoculated-6.22 1984, read-7.2 1984)

f SW 581, 721

g SW 561, 627

h SW 561, 587, 627

i SW 561, 627, 721

表8. 玉米 PI 種源抗南方型銹病篩選[a]

Table 8. Screening of maize PI germplasm for resistance to southern rust (*P. polysora*)[a]

試驗次別 (Expt. No.)	篩選數目 (Accessions screened)	銹病反應 (Rust reaction)[d]		
		R	M	S
1[b]	330	0	10[e]	320
2[c]	13	0	1[f]	12

a 試驗在溫室內進行 (Experiments were conducted in the greenhouse)

b 播種—73.5.18，接種—73.5.30，調查—73.6.9，(sown-5.18 1984, inoculated-5.30 19, read-6.9 1984)

c 播種—73.6.12，接種—73.6.22，調查—73.7.2，(sown-6.12 1984, inoculated-6.22 1984, read-7.2 1984)

d R—抵抗型 (resistant), M—中抗型 (moderate), S—感病型 (susceptible)

e PI311, 315, 437, 438, 439, 445, 448, 451, 461, 475.

f PI311

表9. 玉米351母本改良系（IMP）抗南方型銹病篩選[a]

Table 9. Screening of IMP breeding materials for resistance to southern rust (*P. polysora*)[a]

試驗次別 (Expt. No.)	篩選數目 (Accessions screened)	銹病反應 (Rust reaction)[e]		
		R	M	S
1[b]	80	0	6[e]	74
2[c]	6	0	2[f]	4

a 試驗在溫室進行 (Experiments were conducted in the greenhouse)

b 播種—73.5.15，接種—73.5.22，調查—73.6.1，(sown-5.15 1984, inoculated-5.25 1984, read-6.1 1984)

c 播種—73.6.12，接種—73.6.25，調查—73.6.30，(sown-6.12 1984, inoculated-6.22 1984, read-6.30 1984)

d R—抵抗型 (resistant), M—中抗型 (moderate), S—感病型 (susceptible)

e IMP2, 6, 49, 52, 66, 79.

f IMP 30, 66.

討　論

普通型銹病在美國曾有35%減產之報導，它可影響植物鮮重、穗長、穗徑、子實千粒重及株高等[(8)]，南方型亦可造成4至45%之減產[(13)]，顯然銹病所造成之減產，端視玉米在何生長期受感染及嚴重程度而定，本省尚未有此方面之研究。

誠如孫氏等[(1)]所言，本省玉米有兩種銹病，當時普通型銹病比較重要，但目前可能南方型比普通型更具威脅性，此乃因為當時玉米之種植面積較小，而且多集中在秋季裡作，生長季節氣溫較低，僅適合於普通型銹病之發生，而由於新推廣之臺農育 351號具有抵抗性，所以普通型銹病只有在原來推廣栽培品種上發生。雖然臺農育 351號抗普通型銹病但不抗南方型，而且生長期較長，所以在春作末期氣溫升高時南方型銹病就開始發生，秋作生長初期氣溫仍高亦適合於南方型銹病之危害，加上甜玉米之引進，幾乎經年都有人不定期栽培，更提供終年不斷之接種源，遂造成南方型銹病之猖獗，因為臺農育 351號抗普通型銹病，而它是未來幾年內主要之栽培品種，預期普通型銹病不會威脅到玉米之生產，南方型銹病即使在春作生長末期發生，對產量之影響可能有限，值得憂慮的是秋作若早期開始即被南方型銹病嚴重危害，則產量可能會大受影響，因此抗病育種必須加緊，期能育出同時抗此兩種銹病之品種。

抗病篩選時所需要之接種源若在室內培養其優點為接種源可以維持終年不斷，普通型銹病與南方型銹病可分開培養，避免交互感染，夏胞子之新鮮度容易控制，發芽率高，不含其他雜菌，其缺點則無法大量繁殖，並需較多之人力，若從田間直接採集其缺點為受生長季節之限制無法適時獲得發芽率良好之接種源，而且會有兩種銹病在同一葉片上交互感染之慮，胞子之新鮮度及發芽率較低，也常含有其他種類之病菌及雜菌，其優點則勿需專人培養並可一次獲得大量之接種源。抗病測定若採用病圃在田間任其自然感染則最省人力並且一次可測定許多品系，但其缺點為發病常不易控制，受季節性之影響，而且常有複合感染，增加抵抗性判斷之困擾，幼苗測定法，小規模在室內進行容易控制發病與環境。

P. sorghi 已報告有14個生理小種[(10)]，*P. polysora* 也有9個生理小種[(2)]，因此同一品系在不同試驗中所表現之反應不一，可能與接種源中所含生理小種之比例有關，目前正設法獲得判別品種以便證實。又試驗並非在同一時間進行，其間溫度是否會影響寄主與病菌間之相互關係，導至病徵表現上之差異仍有待研究，目前僅知南方型適合於較高溫 (23—30°C)，普通型適合於較低溫 (16—23°C)，而本研究大致均在上述溫度範圍內進行。又 *P. sorghi* 之中間寄主 (alternate host) 為

黃花酢醬草 (*Oxalis corniculata*)[7]，本省有此寄主，但依 Hooker 及 Yarwood 氏[7]之方法未獲多胞子之發芽，自然界亦未發現黃花酢醬草有春子器（aecium）及春胞子（aeciospore），此與美國之情形相似，其初次感染源 (primary inoculum) 懷疑係來自墨西哥之黃花酢醬草上之春胞子，*P. polysora* 則未有中間寄主之報導。

本試驗已獲許多抗普通型銹病之品系，可做爲育種之材料，許多玉米品系亦已證實有一個或一個以上之顯性抗病因子[2,3-6,9]，所以要育成適合本省栽培之抗普通型銹病品種應該不難，目前之臺農育 351號已具有抵抗性，宜再尋找優良之抗南方型銹病品系，設法將其抗病因子同時導入一個品種中，達到完美之境界。

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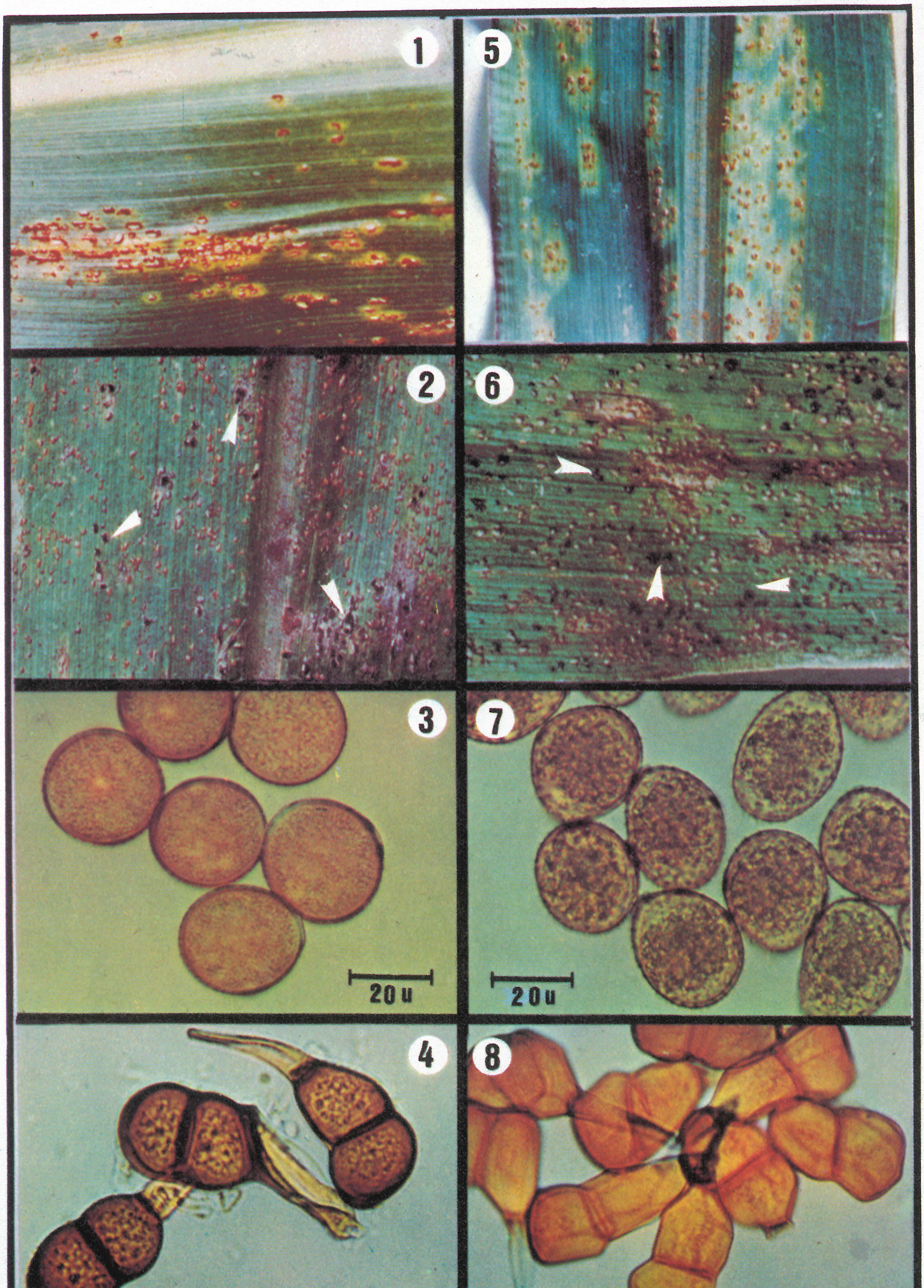
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圖版說明

圖1—4：普通型銹病，1—夏胞子堆時期，2—多胞子堆時期（白色箭頭指示）3—夏胞子，4—多胞子。

Fig. 1—4. Common rust (*Puccinia sorghi*), 1—Uredial stage, 2—Telial stage (white arrows), 3—Uredospores, 4—Teliospores

圖5—8：南方型銹病，5—夏胞子堆時期，6—多胞子堆時期（白色箭頭指示）7—夏胞子，8—多胞子。

Fig. 5—8. Southern rust (*P. polysora*), 5— Uredial stage 6—Telial stage (white arrows), 7—Uredospores, 8—Teliospores.

Diagnosis of Corn Rusts and Screening for Rust Resistance[1]

C. C. Yeh[2]

Summary

Experiments were conducted to differentiate common rust from southern rust of maize and to screen germplasm of maize for rust resistance. The uredia of *Puccinia sorghi* Schw., the cause of common rust, are circular to elongate, chocolate-brown, often with host epidermis attached. Uredospores are cinnamon-brown, spherical. Telia are erumpent, chocolate-brown to black. Teliospores, which replaced the uredospores in the pustules, are chocolate-brown to black-brown, smooth, often with thickening and darkening apex. The uredia of *Puccinia polysora* Underw., the cause of southern rust, are light cinnamon-brown, circular. Telia are circular, chocolate-brown to black and remain covered by the epidermis longer than in common rust, often appeared in circules around the uredia. Uredospores are yellowish to golden, ovoid. Teliospores are chestnut-brown, angularly ellipsoid or ovoid, without obvious thickening of apex. Inocula or uredospores of the two rust fungi for screening tests were separately cultured on the detached leaves of a susceptible corn cultivar in petri plates. Test corn seedlings with 4 to 6 expanded leaves were sprayed with uredospore suspension. Six to ten days after inoculation, the reaction was graded. The grading system consisted of three categories, i. e. resistant (R)-no visible symptoms or chlorotic spots; moderate (M)-necrotic flecks, or with medium, not fully developed uredia; susceptible (S)-with fully developed uredia which sporulated abundantly. Nine-hundred and eighty four lines/varieties were screened. Tainungyu 351 and many other lines were resistant to common rust and only a few lines such as ER 172, ER 418, ER 325 and ER 504 were resistant to southern rust. Taiwan 5 and Tainan 11 were susceptible to both rusts.

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番茄抗南方根瘤線蟲品種篩選[1]

楊一郎　葉坤地[2]

摘要：供試101個番茄品種（品系）之抗南方根瘤線蟲（*Meloidogyne incognita*）篩選結果，有15種表現抵抗性，4種表現中感性，82種表現感病性。感病性品種形成嚴重根瘤，植株矮化，果實產量銳減，品質降低，早期枯葉死亡。低抗性品種在幼苗期，少數幼根可形成極小根瘤，惟其成株則未見有大型根瘤。

南方根瘤線蟲（*Meloidogyne incognita* Chitwood）爲害本省番茄、麻類、瓜類及果樹類等多數旱地作物。以番茄(*Lycopersicum esculentum* Mill.)被害較嚴重。根瘤線蟲之分佈甚廣，在本省以 *M. incognita* 爲最普遍。本省栽培之番茄及瓜類，大多數爲感病性品種，被害根部形成嚴重之大小根瘤，植株矮化、枯葉，若遇雨季則併發菌類病害（complex diseases）而根腐死亡，造成嚴重枯萎病害，致產量與品質受損至鉅[1,2,5]。本線蟲之寄主植物範圍甚廣[1,3,5]。本試驗收集國外及本省大部分番茄品種（系），於民國66年至67年在原臺南棉麻試驗分所，進行抗南方根瘤線蟲（*M. incognita*）篩選及研究工作。

將黃麻之根瘤線蟲，經以棉花（Delta pine 16），菸草（NC95），番茄（Rutgers），辣椒（California wonder），西瓜（Charleston Gray），落花生（Florunner），玉米（Minn A401）等美國之 Sasser 提供之檢定植物及方法[2,4]，檢定結果爲（*M. incognita*）。將此項根瘤經切碎機切碎混合之水溶液爲接種源。

在篩選圃移植 101個番茄品種（系）之幼苗各30至40株，每苗中間種植感病性之盛岡種苗爲對照。每苗根部灌注上述接種源根瘤混合液約 100c.c. 。在番茄生長至結果期間，每週抽查各品種根瘤罹病率，並以盛岡種之根瘤罹病率爲對照[4]。根瘤罹病率計算方法如下：將根部之根瘤形成程度分爲 0、1、2、3、4 等五級。0級爲無根瘤；1級爲 $\frac{1}{4}$ 以下之極少數根部有少數小根瘤；2級爲 $\frac{1}{4}$ 至 $\frac{1}{2}$ 之根部有小根瘤；3級爲 $\frac{1}{2}$ 至 $\frac{2}{3}$ 之根部有大小根瘤，部分根羣發育受阻；4級爲 $\frac{2}{3}$ 以上之根部有大小根瘤，根部受損，植株枯萎。

$$\text{罹病率（\%）} = \frac{n_1+2n_2+3n_3+4n_4}{4(n_0+n_1+n_2+n_3+n_4)}\times 100$$

番茄品種（系）之抗性分爲三類，如次：抵抗性（R級）爲罹病率 0～25%。中感性（I級）爲罹病率 26～70%。感病性（S級）爲罹病率 71%以上。

供試番茄101品種（系）經南方根瘤線蟲（*M. incognita*）篩選圃篩選，統計分析其罹病率，結果如表1及表2。

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表 1. 番茄品種（系）抗南方根瘤線蟲篩選結果

Table 1. Reactions of tomato varieties/lines to the southern root-knot nematode (*Meloidogyne incognita*)

抗性分級（罹病率%） Reaction for root-knot resistance* (% infected)	品種（系）名稱 Varieties or lines	合計 total
抵抗型 (R) (0—25%)	勝利、平和、慧光、試交4號、F-64-202, T-33-1, BWN-18F1, Hawaii 7795, Kalohi, Anahu, Kewalo, Atkinson, Romulus-VFN-Hybride F1. R. S, No. 498, VFN-F1, VFN8-17293,	15
中感型 (I) (26—70%)	VF-13L-34-17186, T-111-1, 5094, 5816,	4
感病型 (S) (71—100%)	盛岡7號、雙喜、夏豐、農友1號、幸福、新煇、農友新4號、農友D號、喜燕、 PI129065L. escul, PI128886L. escul, 8-1-2-1, Venus, PI103055L. escul, PI205004L. escul, PI95584, PI128293 L. escul, CL11-0-1-2-0-0, KL I, Sturn, Nagcarlang PI129101L. escul, TK70, CL32-0-1-19-0, PI365916L. Pimp, PI109838, 72T14, PI128887L. escul, PI128289L. escul, 72T6, PI128292 L. escul, CL143-0-4B-1-0, PI109513, PI12859L. escul PI121280L. escul, CL32-0-1-25-0. Santa Cruz (Brazil). PI91913L. escul, Vc48-1 CL122-0-5-3-0, PI128449L. escul, Florida MH-1, VC-11-1, PI128281L. escul, Extase ABC. Napoli 328-902, cal ACE 435-339, Red Rock 484-714, MERit 485-262, Peto MEch II-590-005, cal-J 484-010, Peto. CVF-169-001, MEchEast 22-330-001, VF-145-21-4-17169, VF-13L-17294, CF-145B-7879-17299, VF-145-514-17165, VF-17162, Mech HARN. VF145-21-4p-17297 TROPic-17222, Walter-17103, Manaluic-17191, VF-10-17170, Campbell 34-17215, San Marzano Large Fruited-17251, VF-65-4-17238, VF-428-F2-17131, Homestead FM-61-17157, Early Pak 707-17167, Florida MH1-1-17175, Campbell-36, Campbell 28, VF-145-F5-17221, TK7-74, Roma, Leaty, H1370, Cal ACE 435-339, Homested elite-17158, F-64-197, F-65-126.	82
合計		101

*R : Resistant. I : Intermediate. S : Susceptible.

表 2. 番茄抗南方根瘤線蟲篩選抗性品種（系）罹病率

Table. 2. Reaction of tomato varieties/lines resistant to the southern root-knot nematode (*Meloidogyne incognita*)

品種（系）名稱 Varieties/lines	平均罹病 %. infected ①	抗性分類 reaction for root-knot resistance ②
T-33-1	0	抵抗型 (R_1)
VFN8-17293	1.4	抵抗型 (R_2)
試交4號	4.5	抵抗型 (R_3)
慧 光	5.0	抵抗型 (R_4)
平 和	5.8	抵抗型 (R_5)
F-64-202	7.3	抵抗型 (R_6)
勝 利	8.3	抵抗型 (R_7)
Kewalo	9.87	抵抗型 (R_8)
Anahu	11.5	抵抗型 (R_9)
Atkinson	11.6	抵抗型 (R_{10})
Romulus VFNHybride F-1 . R. S.	11.6	抵抗型 (R_{11})
NO. 498 VFN. F1.	13.5	抵抗型 (R_{12})
BWN-18F1	14.45	抵抗型 (R_{13})
Hawaii 7795	16.25	抵抗型 (R_{14})
Kalohi	21.75	抵抗型 (R_{15})

①Average percentage of root-knot infected rate of tested plants from seedling to mature stages.

②R : Resistant.

由上表可知供試101個番茄品種（系）中，有15種（系）表現抵抗性（R級），4種（系）為中感性（I級），82種（系）為感病性（S級）。上述結果與George (1976) 等報告之番茄品種（系）之抗根瘤線蟲檢定結果相似[5,6]。各供試盛岡種感病性對照植株，皆形成典型之嚴重根瘤。抗性品種之根部及植株在採集收穫後，仍然生長正常而旺盛，而感病性品種之根部及植株枝葉，於根羣形成極多大小根瘤，且細根稀少或因眞菌複合感染引起根腐枯萎或死亡，致產量銳減品質低劣。

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Screening Tomato for the Resistance to Southern Root-knot Nematode *Meloidogyne incognita*[1]

I-lang Yang and Kung-di Yeh[2]

Summary

One hundred and one varieties/lines of tomato were screened in a root-knot nematode nursury for the resistance to *Meloidogyne incognita.*

Fifteen, 4 and 82 varieties/lines, respectively, were found either resistant, intermediate or susceptible.

A few small root-knots were observed in the roots of seedling of resistant varieties and failed to develop in the latter growing stage. The root-knots in the susceptible varieties, however, were more and larger than there in the intermediate and/or resistant varieties.

Susceptible plants also showed symptoms of yellowing, dwarf and decline with poor quality and quantity of fruits.

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木瓜白粉病之田間消長與藥劑防治[1]

簡和順　　王惠亮[2]

摘要：木瓜白粉病在臺灣南部春季發生嚴重，通常於1月份開始發生，至3～4月爲發病最盛時期，4月以後氣溫逐漸上升，雨量增多，發病亦逐漸減少。在網室內以木瓜幼苗進行藥劑試驗，由19種可防治作物白粉病之藥劑中，篩選出防治效果佳，且無藥害產生之藥劑共四種，爲70％可濕性硫黃粉，93％免賴得—S可濕性粉劑，25％布瑞莫乳劑和75％多保淨M—銅可濕性粉劑，以此四種藥劑與植物保護手册現行推薦使用之三種藥劑進行田間藥劑防治比較試驗，於白粉病發生初期開始，每隔10天噴藥一次，連續噴施三次，結果顯示此四種藥劑與已推薦之藥劑均有優異防治效果，又系統性藥劑50％免賴得可濕性粉劑與70％可濕性硫黃粉劑交替使用亦可得優異防治效果。

關鍵字：木瓜，白粉病，藥劑防治

木瓜（*Carica papaya*）白粉病（*Oidium caricae* Noack）發生在低溫乾燥季節，尤以每年一月至四月最爲普遍，爲害幼苗之莖部、葉柄、葉片，引起葉片黃化脫落，使植株衰弱。即使成株之葉柄、葉片及果實爲害情形亦甚嚴重，使葉片直立枯黃、落葉，導致開花不結果或降低果實之品質。

現經濟部頒行之植物保護推廣方法手册內列有四種防治藥劑，但19.5％白粉克可濕性粉劑及50％百蟎克可濕性粉劑在苗期使用時，常發生藥害，引起落葉。又18.6％賽福寧乳劑及50％免賴得可濕性粉劑之防治效果，已不如前，有鑑於數年來就推出很多種對白粉病有效防治藥劑，爲求防治效果更佳而對幼苗期無藥害之藥劑，並瞭解木瓜白粉病在田間消長情形，以便確定噴藥時期之參考，供農民有效防治木瓜白粉病而進行本試驗。

材料與方法

一、木瓜白粉病田間消長調查

調查木瓜白粉病之試驗園，設置於鳳山分所，木瓜栽植日期爲民國71年10月17日，栽植品種爲日陞種（Sunrise），調查之方法爲每隔10天調查一次，每次調查40株，每株由完全展開之心葉向下調查10葉，計算其病葉數及病斑數目。溫度與雨量之資料取自本分所設置之氣象臺。

二、木瓜白粉藥劑選汰試驗

在網室內以市面上可以買到之19種防治各種作物白粉病之藥劑，進行對木瓜幼苗白粉病藥效與藥害試驗，以篩選出防治效果佳且對木瓜幼苗無藥害之藥劑，進行田間防治試驗。19種藥劑及使用濃度分別爲50％免賴得可濕性粉劑（Benlate W. P.）3,000倍，25％布瑞莫乳劑（Nimrod E. C.）2,000倍和3,000倍，25％依瑞莫水懸粉劑（Micurb super F.）1,500倍和2,000倍，93％免賴得—S可濕性粉劑（Benlate-S W. P.）400倍和600倍，70％可濕性硫黃粉劑（Sulfur W. P.）400倍和600倍，19.5％白粉克可濕性粉劑（Karathane W. P.）1,500倍、多保淨—M銅可濕性粉劑（Topsin-M Do W. P.）600倍，50％百蟎克可濕性粉劑（Morocide W. P.）2,000倍，18.6％賽

1.臺灣省農業試驗所　研究報告第1172號。
2.本所鳳山熱帶園藝試驗分所植物保護系助理。臺灣省　高雄縣　鳳山市。

福寧乳劑 (Saprol E. C.) 1,000倍，30%三得寧乳劑 (Sapxin E. C.) 1,000 倍和 1,500倍，5% 三泰芬可濕性粉劑 (Bayleton W. P.) 1,500 倍和 2,000倍，10%得滅多乳劑 (Denmert E. C.) 1,000倍和2,000倍，20%得滅多可濕性粉劑 (Denmert W. P.) 1,000 倍和2,000倍，30%大脫蟎乳劑 (Acrex E. C.) 1,000 倍和2,000倍，60%普伏丹可濕性粉劑 (Plondrel-C W. P.) 400倍和600倍，25%山陽銅乳劑 (Sanyol E. C.) 500 倍和 1,000倍，21.2%依滅列乳劑 (Fungaflor E. C.) 2,000倍和3,000倍，12.5%芬瑞莫乳劑 (Fenarimal E. C.) 4,000倍，6,000 倍和 8,000倍，25%保您好乳劑 (Sportak E. C.) 4,000 倍，6,000 倍和 8,000 倍。試驗之木瓜品種爲日陞種，木瓜苗以 9 ×8.5 公分之塑膠盆栽植，每處理四重複，每重複 5 株，於白粉病發生開始噴藥，每隔 10天噴藥一次，連續二次，於第一次噴藥後20天調查藥效與藥害情形。

三、木瓜白粉病藥劑田間防治試驗

由網室之藥劑選汰試驗結果，選定四種防治效果優異且對木瓜幼苗無藥害之藥劑如表一所列，與三種推廣使用之藥劑進行田間防治效果比較試驗。本試驗進行二年，試驗品種爲日陞種，第一次田間

表1. 木瓜白粉病藥劑防治試驗

Table 1. The efficacy of different fungicides for the control of papaya powdery milderv in the field

藥劑[a] Pesticides	稀釋倍數 Dilution	噴藥後不同天數之罹病率[b] Disease rate at different days after pesticides treatment			
		第一次田間試驗 The first trial		第二次田間試驗 The second trial	
		20 days	30 days	20 days	30 days
50% 免賴得可濕性粉劑 Benlate W. P.	3000	4.00 b	2.25 a	1.88 abc	3.50 a
19.5% 白粉克可濕性粉劑 Karatane W. P.	1500	3.75 ab	2.50 a	2.75 c	3.00 a
18.6% 賽福寧乳劑 Saprol E. C.	1000	2.50 ab	0.75 a	1.94 bc	2.63 a
70% 可濕性硫黃粉劑 Sulfur W. P.	400	3.25 abc	2.00 a	2.31 bc	3.19 a
93% 免賴得—S 可濕性粉劑 Benlate-S W. P.	400	3.50 ab	1.25 a	1.56 abc	2.81 a
25% 布瑞莫乳劑 Nimrod E. C.	2000	3.00 ab	1.50 a	1.69 abc	2.69 a
75% 多保淨—M銅可濕性粉劑 Topsin-M Do W. P.	600			1.50 abc	2.00 a
50% 免賴得可濕性粉劑和 Benlate W. P. and 70% 可濕性硫黃粉劑 Sulfur W. P. 輪流使用 Used in turn	3000 + 400	3.00 ab	1.50 a	1.88 abc	2.94 a
對照 Control		24.00 c	26.75 b	20.13 d	33.06 a

a) 藥劑每隔10天噴藥一次，連續三次，第一次藥後20天和30天調查。
Fungicides were sprayed three times every 10 days and investigation was made 20 days and 30 days after the first spraying.

b) 統計分析以鄧肯氏多重變域分析法，百分之五差顯著性。
Numbers in each colum followed by the same letter are not significantly different at the 5% probabilits level by Duncan's multiple range test.

試驗木瓜苗於民國70年11月栽植，第二田間試驗於民國71年11月栽植，試驗設計採逢機完全區組設計，於木瓜白粉病發生初期開始，以背負式人力噴霧器，每隔10天噴藥一次，連續噴施三次。噴藥時加3,000倍 CS-7展著劑，藥效調查為第一次噴藥後20天和30天調查，每株由頂端完全展開葉，向基部調查10葉，計算其病葉數及斑點數目，並用下列等級計算罹病度：0代表未發病，1代表每葉1～10個病斑，2代表每葉11～30個病斑，3代表每葉31～50個病斑，4代表每葉51個病斑以上。以下列之公式計算罹病度，並以鄧肯氏（Duncan's）多重變域分析法統計分析，比較百分之五差異顯著性。

$$罹病度 = \frac{\Sigma\ (指數 \times 該指數罹病葉數目)}{4 \times 全部調查葉數} \times 100$$

結　果

一、木瓜白粉病田間消長調查

田間木瓜白粉病發生時期如圖一所示，由一月開始發生，至三月為最嚴重時期，五月以後即不發生，因三～四月間之溫度多在18—22°C之間，且雨量較少最為適宜於發病，五月開始雨量較多且溫度增高，十月至十二月雨量雖少，但溫度高，均不適宜本病發生。

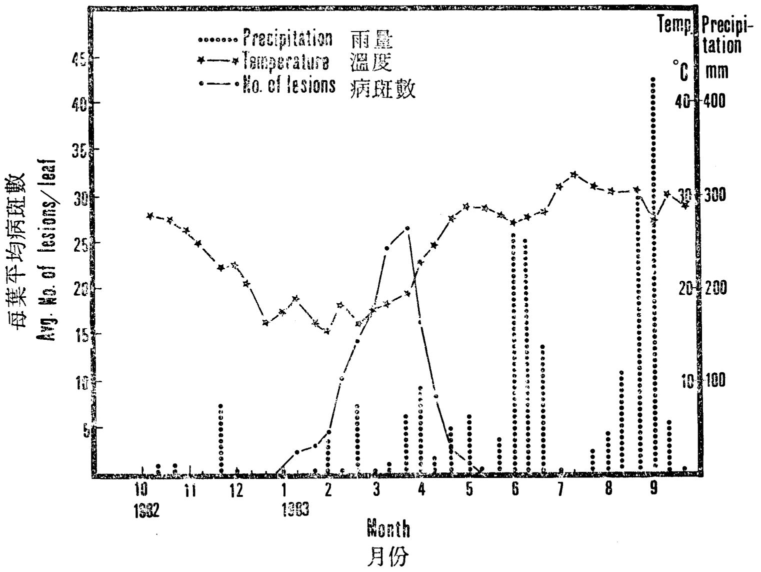

圖1. 田間木瓜白粉病發生時期與溫度雨量之關係

Fig. 1. Relationship among precipitation, temperature and occurrence of powdery mildew of papaya in the field during the period of October, 1982 and September, 1983.

二、木瓜白粉病選汰試驗

以19種可防治各種作物白粉病之藥劑，進行對木瓜幼苗白粉病藥效與藥害試驗中，發現均對木瓜白粉病有優異之防治效果，但19種藥劑中有13種藥劑對木瓜幼苗會產生輕重不一之藥害，包括三種推薦使用藥劑 19.5% 白粉克可濕性粉劑造成木瓜葉片壞疽斑點，50%百蟎克可濕粉劑造成退色黃斑，18.6%賽福寧乳劑造成葉緣壞疽。其他10種藥劑造成木瓜幼苗葉片壞疽斑點，黃斑，葉緣壞疽，心葉停止生長，黃化，落葉，葉片畸形，植株矮化等現象。另外不產生藥害且防治效果優異之藥劑為70%可濕性硫黃粉，93%免賴得—S 可濕性粉劑，25%布瑞莫乳劑、75%多保淨—M銅可濕性粉劑和已推薦使用藥劑50%免賴得可濕性粉劑。因此選用上述有效藥劑進行田間試驗。

三、木瓜白粉病藥劑田間防治試驗

於鳳山分所進行之二次田間防治試驗，結果如表一所示，顯示試驗藥劑70%可濕性硫黃粉 400 倍，93%免賴得一S 可濕性粉劑，25%布瑞莫乳劑、75%多保淨一M銅可濕性粉劑和50%免賴得可濕性粉劑與70%可濕性硫黃粉劑輪流使用，與推廣使用對照藥劑50%免賴得可濕性粉劑 3,000 倍，19.5%白粉克可濕性粉劑 1,500倍和 18.6%賽福寧乳劑比較試驗，於第一次與第二次試驗中，第一次噴藥後20天和30天，試驗藥劑、對照藥劑和對照不噴藥處理比較，均顯現優異防治效果，呈百分之五差異顯著性，但第一次噴藥後30天，各種藥劑處理間差異不顯著。

討　　論

白粉病爲木瓜常見病害之一，其病原菌爲*Oidium caricae* Noack，係屬於子囊菌網（Ascomycetes），白粉菌目（Erysiphales）之一絕對寄生菌類[2]，分佈於臺灣、夏威夷、佛羅里達州、澳洲等地[1,4,6]。本病發生於乾旱季節，南部與東部以春季爲甚，十二月至隔年四月隨處可見[1]由木瓜白粉病田間消長調查結果顯示，本病以初春最爲嚴重，於三月有一發病高峯，至四月開始下降，五月以後即不發病，由氣象資料分析，本病發生之適當溫度在18—22°C之間，太高之溫度，本病即不發生，顯示本病原菌對熱之抵抗性較弱，高溫對其不利。同時多雨季節亦不利於本病之發生，此可能與雨水會對分生胞子柄造成機械傷害、多水情況下胞子發芽不良有關[2]，因此本病之發生與溫度、雨量有密切之關係。

木瓜白粉病目前以化學藥劑防治最爲有效，孫氏[1]曾報告，本病之藥劑防治可用石灰硫黃粉，簡氏，王氏等[3]認爲白粉克可濕性粉劑與乳劑，蟎離丹，百蟎克，免賴得均有良好之防治效果。Obrero[5]報告以鋅錳乃浦加展著劑出來通 1956，可有效防治本病。但木瓜對藥劑甚爲敏感，使用不當極易產生藥害，尤以木瓜幼苗爲甚。由網室內以木瓜幼苗進行之藥害與藥效選汰試驗結果顯示，19種供試藥劑均顯現優異的防治效果，但其中只有一種推廣使用藥劑 50%免賴得可濕性粉劑和五種新藥劑25%布瑞莫乳劑，25%依瑞莫水態粉，93%免賴得一S 可濕性粉劑，70%可濕性硫黃粉，75%多保淨一M銅可濕性粉劑，對木瓜幼苗不產生藥害，其他13種藥劑包括推廣使用藥劑 19.5%白粉克可濕性粉劑，50%百蟎克可濕性粉劑和18.6%賽福寧乳劑，經二次噴藥後，均會產生輕重不同之藥害，因此於木瓜幼苗時，應謹愼選用防治藥劑，以避免藥害產生。

由網室選汰試驗中選用四種對木瓜幼苗不產生藥害之藥劑，與三種已推廣使用之藥劑，進行田間防治比較試驗，結果顯示此四種藥劑均有優異之防治效果，且與三種對照藥劑差異不顯著。試驗中系統性藥劑免賴得可濕性粉劑與非系統性藥劑可濕性硫黃粉劑輪流使用，亦可獲得良好的防治效果，由於木瓜白粉病菌是屬於絕對寄生菌，變異較多，抗藥性極易發生，因此系統性與非系統性藥劑輪流使用，可避免抗藥性產生。

綜合本試驗結果，木瓜白粉病之藥劑防治，應於發病初期開始噴藥，選用之藥劑應注意苗齡大小，以避免產生藥害，噴藥時每隔 10天一次，連續噴施二～三次，施用時需混合展著劑，以增加其防治效果，噴藥時應噴佈於葉片之上下兩面及莖部，以達有效防治本病。

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Seasonal Incidence and Chemical Control of Powdery Mildew of Papaya in Taiwan[1]

H. S. Chien and H. L. Wang[2]

Summary

Powdery mildew of papaya, caused by *oidium caricae* Noack, started in January, and became severe in March and April. in southern Taiwan. The disease decreased after April due to the warming temperature and raining season. In order to obtain effective fungicides for the control of this disease, 19 chemicals were preliminarily tested on the papaya seedlings in the net-house and the results indicated that 70% sulfur W. P., 93% Benlate-S W. P., 25% Nimrod E. C. and 75% Topsin-M do W. P. were satisfactory. The efficacy of these four fungicides were compared in the field test with the three recommended fungicides listed in the plant protection manual. The Fungicides were sprayed three times every ten days after the disease became visible. The results showed that they were as effective as the recommended fungicides. The alternate use of 50% Benlate W. P. and 70% sulfur W. P. also gave a satisfactory control in the field.

Key words : Papaya, powdery mildew , chemical control.

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銷日菊花害蟲檢疫處理—田間套袋與浸漬法之利用[1]

王清玲　林瑞桐[2]

摘要：銷日菊花害蟲檢疫問題可以田間花蕾套袋與切花後藥液浸漬莖葉配合應用而獲得解決。田間自花蕾尚未展開時即予以套袋，可杜絕爲害花部害蟲之發生，並減少田間之施用殺蟲藥劑。切花後浸漬切花之莖葉於殺蟲劑與殺蟎劑之混合稀釋液中，可毒殺附著莖葉上之害蟲及害蟎。此種方式處理之菊花無害蟲存在，且任何品種之菊花均可應用。以往白色花浸藥後因汚斑而品質降低之現象將可消除。經處理之切花其保鮮期不受影響。

銷日菊花因面臨日方海關植物檢疫人員嚴格的害蟲檢查，每因害蟲防治不完全而隨時受到被燻蒸的威脅，至今尙未能有一妥善有效的處理對策。自63年由林萬成氏等報告以藥液浸漬處理菊花之殺蟲效果最佳且無藥害後[5]，浸漬法即一直應用於銷日菊花。本所亦已於71年做過浸漬用農藥效果的重新篩選[1]，將常用的29種殺蟲劑，殺蟎劑的浸漬效果重新做一測定，以提高藥劑治蟲效果，雖然如此，仍然不能避免浸後花心不易充分乾燥，以及白色花易被藥液汚染的缺點[4]。以燻蒸法與燻煙法處理菊花，已於72年做過多次試驗，因在使蚜蟲，薊馬與二點葉蟎全死的藥劑用量與處理時間之下，必涉及切花藥害或日後保鮮問題，故僅可視爲一種在精確控制下才可進行的處理，並不適合實際之大量操作[2,3]。

在配合田間實際的外銷出貨操作上，可行的害蟲檢疫處理必須爲方法簡單，而且效果好，無損鮮花品質。因此，本文旨在報告應用以往累積的各項檢疫處理經驗，加以實際情況的考慮，而進行的檢疫處理試驗結果。

材料與方法

一、套袋處理：

套袋：透明 PE 袋，長 17cm，寬 13cm ，袋上具有直徑約 0.2～0.5mm 之針孔，孔間距2～5mm，遍布全袋。

地點：田尾鄉柳鳳村菊花專業區，選擇生長至適當時期之菊田五處。分屬謝、周、施、羅姓農友。

品種：黃秀鳳、白鳥。

方法：自花蕾生長至花萼將展開，即將露出其舌狀花時（直徑約 2cm 左右），即予以套袋。套袋下端以魔繩（即中間夾有鐵線之塑膠繩）紮束固定於莖部。

時間：72年11月11日開始首次套袋試驗，分別於16日、18日、24日採樣調查。12月 2 日再度之套

1.臺灣省農業試驗所　研究報告第1173號。

2.本所應用動物系助理研究員，計畫助理。臺灣省　臺中縣　霧峰鄉。

袋試驗，則於 7 日、9 日、13日採樣調查。

二、浸漬處理：

除71年菊花害蟲藥劑浸漬試驗中篩選出的效果較佳之大克蟎 (Dicofol) 42 EC 外，另以目前對本省多種作物上二點葉蟎較有效的百蟎克 (Acricid) 25 WP，大脫蟎 (Acrex) 30 EC，覆滅蟎 (Formetanate hydrochloride) 50 SP, Danital 10 EC[6] 等之500至2000倍液，測試其對葉片上二點葉蟎 (*Tetranychus urticae*) 之殺滅效果。

殺蟲劑則測試第滅寧 (Deltamethrin) 2.8 EC，芬化利 (Sumicidin) 20 EC，亞素靈 (Azodrin) 55 EC，克硫松 (Celathion) 45 EC, Mavrik 2E 25 EC，之1000至8000倍液對蚜蟲 *Aphis gossypii*, *Myzus persicae*) 之效果，浸漬時將切花直立浸入藥桶，只浸及花蕁套袋以下的莖葉部位等，浸漬時間約爲 5—10秒，切花稍予上下動搖，以免藥液不能充分浸濕葉部。

浸漬試驗用的二點葉蟎，蚜蟲採自田尾的廢棄菊花園中，故數目相當多。此外亦以管理良好，生長至一般銷日標準的切花，做浸漬後藥害的觀察。

結　　果

一、套袋處理：

(一) 害蟲發生情形：

花蕾尙未展開即予以套袋的菊花，經 7—10天後到達切花期。通氣孔直徑 0.5mm 與 0.2mm 套袋內之菊花，經套袋 7 日後檢查，均無任何種類的昆蟲侵入。此時菊花直徑約 3cm。套袋至14日時，菊花已充分展開，直徑約 5cm，此時 A 袋 (通氣孔爲 0.5mm) 內曾發現有少數薊馬侵入。B袋 (通氣孔爲 0.2mm) 仍未有任何昆蟲侵入。而同一田區緊鄰套袋旁的未套袋菊花上，仍有爲數甚多的蚜蟲，薊馬存在，甚且更有夜盜蟲 (*Spodoptera litura*) 發生 (表 1)。

表1. 田尾菊花專業區五處試驗田中套袋與未套袋菊花上害蟲發生數目比較。

Table 1. Insects found on chrysanthemum blooms with or without protection bags.

地點 Location	套袋日數 Days of. bagging	套袋 Bag	花數 No. of bloom	總蟲數 No. of insect: 蚜蟲 Aphids	薊馬 Thrips	夜盜蟲 Army worm
第一區 I	7	套袋 A[a]	18	0	0	0
		未套袋	24	1	3	1
	14	套袋 A	17	0	3	0
		未套袋	40	49	14	3
第二區 II	7	套袋 A	13	0	0	0
		未套袋	33	6	3	0
	14	套袋 A	24	0	2	0
		未套袋	28	120	9	0
第三區 III	7	套袋 A	14	0	0	0
		未套袋	32	22	11	0
第四區 IV	5	套袋 A	2	0	0	0
		套袋 B	2	0	0	0
		未套袋	28	181	24	1
	7	套袋 A	3	0	0	0
		套袋 B	7	0	0	0
		未套袋	30	24	8	0
	11	套袋 A	17	0	0	0
		套袋 B	58	0	0	0
		未套袋	31	153	4	1

地點 Location	套袋日數 Days af. bagging	套袋 Bag	花數 No. of bloom	總蟲數 No. of insect 蚜蟲 Aphids	薊馬 Thrips	夜盜蟲 Army worms
第五V區	5	套袋 A	7	0	0	0
		套袋 B	7	0	0	0
		未套袋	24	152	2	3
	7	套袋 A	6	0	0	0
		套袋 B	15	0	0	0
		未套袋	8	22	3	0
	11	套袋 A	42	0	0	0
		套袋 B	38	0	0	0
		未套袋	36	207	40	1

a：套袋A—氣孔直徑 0.5mm 孔間距 0.5cm
Holes on bag with 0.5mm diameter were 0.5cm apart from each other.
套袋B—氣孔直徑 0.2mm 孔間距 0.2cm
Holes on bag with 0.2mm diameter were 0.2cm apart from each other.

（二）切花品質之影響：

經過套袋的切花，與未經套袋的切花，在生長速度，花型、大小、花色上完全一致。因上下均有細孔密佈，空氣流通無礙，袋內溫度的增加甚微。在氣溫 25.5°C 時，無氣孔之袋內溫度達 29°C 具直徑 0.2mm 氣存之套袋內溫度 26.7°C，僅上升 1.2°C 在氣溫 17.5°C 及 20.5°C 時，套袋內溫度均未較袋外昇高。雖日照下，大多亦無水氣累積袋上之情形，且透光性良好，故對切花本身尚未發現有任何影響品質的現象。

二、浸漬處理：

經過套袋後的菊花，浸漬處理是僅針對葉部的二點葉蟎或蚜蟲而進行，故以浸漬莖葉部爲主，花萼以上部分均不浸漬。

浸漬之結果顯示，殺蟎劑中之大克蟎500倍，大脫蟎500倍，覆滅蟎1000倍與百蟎克1000倍混合浸漬切花之葉部，對其上之二點葉蟎有極佳之效果。浸後24小時二點葉蟎完全死亡。各殺蟎劑對切花之葉部有不同之影響，如選擇其對葉部影響最小者，則其優先順序依次爲：百蟎克、Danital、大克蟎、覆滅蟎、大脫蟎（表2）。

表 2. 殺蟎劑浸漬菊花葉蟎之效果

Table 2. Effect of various acaricides on 2-spotted spider mites on chrysanthemum.

藥劑 Acaricide	二點葉蟎死亡率（立即/24小時） Mortality (Ins./24hr.) 500X	1000X	2000X	對菊花影響[a] Influence on chrysanthemum 500X	1000X	2000X
大克蟎 Dicofol 42EC	100.0 100.0	90.2 90.2	76.5 78.5	2	2	3
覆滅蟎 Fermetanate h. 50SP	84.6 88.8	74.4 100.0	70.0 84.6	2	3	3
百蟎克 Acricid 25WP	87.5 100.0	70.9 100.0	— 100.0	4	4	4
大脫蟎 Acrex 30EC	85.0 100.0	82.5 100.0	79.2 98.3	1	1	1
Danital 10EC	80.5 93.9	86.9 95.7	36.5 95.0	2	2	2

a 數目愈低者表示對葉片有愈大之傷害。
Heavier injury was found on leaves in treatment with lower number.

表 3. 殺蟲劑浸漬菊花蚜蟲之效果

Table 3. Effect of various insecticides on aphids on chrysanthemum.

藥 劑 Acaricide	蚜 蟲 死 亡 率（立即/24小時） Mortality (Ins./24hr.)			
	1000X	2000X	4000X	8000X
第 滅 寧 Deltamethrin 2.8EC	100.0 100.0	100.0 100.0	100.0 100.0	100.0 100.0
亞 素 靈 Azodrin 55EC	90.6 96.9	82.8 96.8	92.6 96.8	—
芬 化 利 Sumicidin 20EC	90.3 96.5	36.9 92.3	83.3 83.3	—
克 硫 松 Celathion 45EC	90.5 95.2	77.4 85.5	90.9 81.8	—
Mavrik 2E 25EC	91.9 97.3	90.0 90.0	94.8 94.8	—

殺蟲劑中以第滅寧效果最好，稀釋至8000倍液，浸後之蚜蟲均立即死亡（表 3 ）。

以百蟎克1000倍與第滅寧8000倍混合浸漬切花莖葉，效果與單獨使用者一致。

討　　論

本試驗中所用的套袋，其特點爲花蕾尙未展開即予套起，套袋具多數小通氣孔，並以魔繩固定套袋下端。其有數項優點：

一、保護花部，避免害蟲入侵：

試驗中所用套袋，其套袋時期與袋上通氣孔均與目前一般在菊花上所使用者不同。外銷香港等地、或內銷的切花，是在花部已大致展開，即將採收前一、二日方予套袋，此時花部可能已潛伏著多數的蚜蟲、薊馬等小型昆蟲，而幼小齡期的夜盜蟲、玉米穗蟲等也經常因疏忽而被套在袋內。這些已套在袋內的昆蟲，因得到一層套袋的保護，反而更能大量繁衍、迅速生長，因此經常在菊花的老式套袋內，發現比不套袋更多的蚜蟲。在換用本試驗特製之套袋後，因套袋時期較早，且袋上通氣孔較小，數目較多、較密，只要袋上之小孔在 0.2mm 之範圍內，任何昆蟲均無法侵入，澈底消除薊馬、蚜蟲、夜盜蟲、玉米穗蟲等爲害花部的問題。

二、減少殺蟲劑的施用：

開花期的施藥一直爲農友所重視，這一時期花部需要妥善保護，以免被蟲所害，一般均於花期每週至少噴藥一次，故自套袋至切花至少需噴 2 ～ 3 次。而套袋菊花，因花部已妥善保護，完全不必施用任何殺蟲劑，故而減少農藥用量，節約施藥人工。

以套袋保護的菊花，在切花後再予以藥劑浸漬莖葉處理，以消除莖葉部的所有害蟲及害蟎。銷日菊花以此種方式保護及處理，將有下列優點：

一、切花上絕對無任何害蟲及害蟎存在。

花部因有套袋保護，故無害蟲存在，尤其是蚜蟲與薊馬，以田間施藥甚難使之根絕，以套袋保護

則可使之在花部絕跡。

莖葉部分均以原先一直沿用之浸漬法處理，但是使用之藥劑種類則有改變。浸漬法中殺蟎劑或殺蟲劑之毒效隨田間防治用藥之變更而日新月異，必須不斷測定藥效，則浸漬處理之效果將更理想。

二、處理後的菊花無藥害，不影響保鮮。

完全以浸漬法處理菊花害蟲，不但浸後白花難保潔白。而且花心部因尚未展開，隱匿其中的薊馬很難浸到，花心一旦浸濕後，再乾燥又頗爲費時、困難。完全以燻蒸處理，則須各項條件控制極爲精確，舉凡溫度、濕度、時間、藥量、品種、花材等嚴格控制，且易產生藥害。以本試驗的方法處理菊花，將完全沒有以上缺點，處理後的菊花即無藥害，又不影響日後的瓶插。

三、任何菊花均可使用，無品種之限制或差異。

菊花的品種很多，尤以外銷日本者，必須迎合日方市場之需要，幾乎每年均推陳出新，有新品種出現。以此種套袋與浸漬的方式處理菊花，不致於菊花因品種不同而有相異之效果，任何品種之菊花均可應用。

四、提高白花之品質

日本市場對白色菊花的需求量較高，其次方爲黃色及紅色。然而本省外銷之白菊一直以浸藥處理，白花上殘留之藥液乾後均形成褐色污斑，因而嚴重影響本省白菊之品質，無法達到對方要求之標準。爲菊花銷日的一個重要瓶頸。現如改以此法處理，則白花不但無蟲，而且自始未沾藥液，將保持其品種原先所具有之特色，花色免遭污染。

五、可配合各種銷售運輸方式。

因一切處理均在裝箱前即已完成，故不但適合具有時效的空運銷日菊花，其它運輸方式亦無限制。

田間防治的充分配合，固然是檢疫處理成功的前階。但無論如何施藥，均只能減少害蟲密度，而無法使之根絕，因此，針對植物檢疫而進行的特殊害蟲處理在目前而言仍是必須的。

以切花後浸漬的應用，再配合以切花前田間的套袋特殊處理，將使本省銷日菊花害蟲的檢疫問題獲得解決。

試驗中所用套袋，除應用銷日菊花外，並可考慮其價格與人工而應用於內銷或外銷其它地區的菊花上。此種套袋除杜絕害蟲發生，減少農藥施用外，其通風性亦較舊式菊花套袋爲佳，減少舊式套袋對花部的不良影響。而針對不同要求產生的不同形式或品質套袋對菊花的效果及影響，則尚待繼續探求。

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Study on the Quarantine Treatments of Insect Pests on Chrysanthemum Cut Flowers---The Application of Protection Bags and the Improved Dipping Methods[1]

C. L. Wang and R. T. Lin[2]

Summary

Transparent PE bags (13×17cm) fully covered with holes (dia. 0.2—0.5 mm) were used to protect chrysanthemum blooms in field. Young buds were covered and protected with these bags prior to the appearance of any petals, and these buds growing and blooming inside the bags. The change of attack of insect pests was hence significantly eliminated or avoided depending on the size of holes on bags.

After cutting, dipping the stem below the flower head in diluted insecticides and acaricides would kill the aphids and mites stayed on leaves. Acricide 25 WP and Decis 2.8 EC were the most effective chemicals screened in this experiment.

The application of the proper protection bags on buds and the improvement of dipping method offered insect-free cut flowers and eliminated the amount of insecticides used in field. Blooms, especially those in white color were not polluted with insecticides. And the keeping period of cut flowers was not influenced.

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The Occurrence of Insecticide Resistance in Three Lepidopterous Pests on Vegetables[1]

by

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Abstract : The imported cabbageworm, *Pieris rapae* Boisduval ; the tobacco cutworm, *Spodoptera litura* Fabricius ; and the cabbage looper, *Trichoplusia ni* Hübner, were sampled from several major vegetable growing areas for the insecticide susceptibility study. For each species, susceptibilities differ among sampled populations resulted from resistance. The finding of this investigation indicated that the imported cabbageworms were free from the resistance problem and chemical control is a very effective measure for controlling this pest. The cabbage loopers are sensitive to neither mevinphos nor carbofuran and are very sensitive to the insecticidal action of synthetic pyrethroids. The test results clearly showed that resistance had developed in tobacco cutworms and the degree of resistance varied from region to region. The highest resistant ratios observed in tobacco cutworm were 63.0 for mevinphos, 79.0 for carbofuran, 13.0 for permethrin and 4.1 for fenvalerate.

In general, the synthetic pyrethroids are still the most effective agents for controlling the three tested pest species, but the organophosphorus and carbamates have encountered resistance problem in both cabbage loopers and tobacco cutworms.

Introduction

Three important vegetable lepidopterous pests, the imported cabbageworm, *Pieris rapae* Boisduval ; the tobacco cutworm, *Spodoptera litura* Fabricius ; and the cabbage looper, *Trichoplusia ni* Hübner, were usually controlled chemically in Taiwan. An insecticide resistance survey carried out in 1980-81 by this laboratory had clarified the effectiveness of several officially recommended insecticides for the control of the diamondback moth, *Plutella xylostella* (L.)[(5)], another important vegetable pest. The

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serious situation encountered in the diamondback moth implied that the resistance problem should not be overlooked in other pests. Since the resistance information is urgently needed in field to select the best or the most reasonable insecticide, Taiwan Agricultural Research Institute has decided to find out to what extent the resistance problems have developed in three above mentioned pests. Currently, more than thirty insecticides are registered for cruciferous vegetable pests control [12] and their effectiveness have not been carefully re-examined ever since the registration. This study, performed similarly to that for the diamondback moth, was intended to identify : (1) whether the resistance has already occurred or not, and (2) whether the resistance has caused the threats in current control practices.

Materials and methods

Insects were sampled from several major vegetable growing areas for the insecticide susceptibility studies. Each species was collected according to the stages which were suitable for rearing enough number of insects for the necessary test. Enough imported cabbageworms can be easily collected from field and no rearing from generation to generation is necessary. The egg mass of tobacco cutworms usually is the most convenient stage for collecting and enough larvae can be obtained from just a few egg masses. If not enough egg masses were collected, one or two generations of rearing is needed to provide enough larvae for the tests. The cabbage loopers were collected and reared in the laboratory because the occurrences of looper's larvae and eggs were rather few and sporadical.

Of all three species, only the third instar larvae were used in testing the insecticide susceptibility and the treatments were carried out in the same way as that of the diamondback moth study [6]. All insecticides used were commercially formulated products and the dilutions were made in distilled water. A preliminary test to determine the effective range of insecticide for each sample population was needed before selecting seven evenly spaced testing dosages. The post-treatment holding temperature and relative humidity were 25°C and 80-90%, respectively. The mortality of treated insects was examined 24 hours after the treatment and the results were analyzed in probit.

Results

The susceptibilities of four imported cabbageworm populations to insecticides were compared in Table 1. The susceptibilities were very close in both permethrin and mevinphos studies and only minimum differences were detected in regard to fenvalerate and carbofuran. Although four populations were collected far apart from each other, the extreme resemblance in their insecticide susceptibilities indicated that the imported cabbageworms have not developed appreciable resistance yet. The results also showed that populations were well mixed in Taiwan that an almost homogeneous response can be concluded from every insecticide tested. Obviously, no sign of resistance in this species has created problems in the control practice.

No appreciable difference in the insecticide susceptibility can be found among

Table 1. The susceptibilities of four field strains of imported cabbageworm to four commonly used insecticides

Location	LC_{50}-(Slope)-R. R.			
	Fenvalerate	Permethrin	Mevinphos	Carbofuran
PT	3.1-(0.89)-1.0	1.3-(0.80)-1.0	31.1-(1.03)-1.2	190-(0.94)-6.2
HH	8.4-(0.62)-2.7	1.6-(1.16)-1.3	34.0-(0.78)-1.4	84-(0.37)-2.7
TC	10.1-(0.93)-3.3	1.3-(1.65)-1.0	25.1-(1.26)-1.0	31-(1.07)-1.0
TY	25.1-(1.08)-8.1	3.4-(2.54)-2.7	34.8-(1.12)-1.4	118-(1.29)-3.9

PT : Ping-tung, HH : Hsi-hu, TC : Taichung, TY : Ta-yuan.

Table 2. The susceptibilities of three field strains of cabbage looper to four commonly used insecticides

Location	LC_{50}-(Slope)-R. R.			
	Fenvalerate	Permethrin	Mevinphos	Carbofuran
PT	6.9-(1.25)-2.0	12.2-(2.79)-2.4	4198-(0.85)-3.5	15257-(0.90)-1.9
PZ	8.6-(1.27)-2.5	5.1-(1.25)-1.0	1205-(0.83)-1.0	16990-(0.47)-2.1
HH	3.4-(1.20)-1.0	5.3-(1.66)-1.0	3159-(1.13)-2.6	8170-(0.91)-1.0

PT : Ping-tung, PZ : Pu-tzu, HH : Hsi-hu

different field populations of cabbage loopers (Table 2). The loopers were almost immuned from the insecticidal actions of both mevinphos and carbofuran and whether this insensitivity was induced by insecticides or occurred naturally is still unclear. Judging from the results in Table 2, the synthetic pyrethroids are still good agents for looper's control.

The tobacco cutworm is the most studied species in this investigation, a total of eight field populations from different regions were compared in their insecticide susceptibilities (Table 3). Although the synthetic pyrethroids were the most effective group, three out of eight populations had developed resistance to permethrin but not fenvalerate. The resistance to both mevinphos and carbofuran was clearly demonstrated in Table 3, the highest resistant ratios observed were 63.0 for mevinphos and 79.0 for carbofuran. The sample collected from Hsi-hu, the most intensively cultivated vegetable growing area, has the highest resistance problem. The most susceptible tobacco cutworms were found in a mountainous vegetable field. We suspect that due to the polyphagous nature of this species, the population is not limited within the cabbage field, hence has minimum contact with insecticides.

Table 3. The susceptibilities of eight field strains of tobacco cutworm to four commonly used insecticides

Location	LC_{50}-(Slope)-R. R.			
	Fenvalcrate	Permethrin	Mevinphos	Carbofuran
PT	14.3-(1.00)-2.8	6.0-(0.56)- 1.4	210-(0.51)- 3.3	596-(0.55)- 1.2
LC	7.0-(0.94)-1.3	5.8-(1.40)- 1.4	586-(0.71)- 9.1	1218-(0.34)- 2.4
PZ	12.1-(1.10)-2.3	24.9-(1.27)- 5.9	652-(1.18)-10.0	2035-(0.69)- 3.9
HH	17.7-(0.69)-3.4	25.0-(1.14)- 6.0	4014-(1.33)-63.0	41048-(2.31)-79.0
TC	12.9-(1.04)-2.5	8.0-(0.77)- 1.9	73-(0.54)- 1.1	3443-(0.52)- 6.7
CP	20.9-(0.90)-4.0	55.0-(0.83)-13.0	73-(0.80)- 1.1	1575-(0.71)- 3.0
TY	5.2-(1.00)-1.0	4.2-(0.71)- 1.0	407-(1.11)- 6.4	2113-(0.64)- 4.1
YM	21.3-(1.20)-4.1	4.7-(0.79)- 1.1	64-(0.41)- 1.0	517-(0.30)- 1.0

PT : Ping-tung, LC : Lu-chu, PZ : Pu-tzu, HH : Hsi-hu, TC : Taichung, CP : Chu-pei, TY : Ta-yuan, YM : Yang-ming shan.

Discussion

In Taiwan, the easiest and the most convenient way to control the vegetable pests is by applying insecticides, and the development of resistance in the pest population certainly becomes a risk which usually resulted from the insecticide usage. The insecticide resistance has been detected in the diamondback moth and the same problem may also occur in other vegetable pests. This investigation will help us to re-evaluate the effectiveness of many officially recommended insecticides.

The test result has revealed that the imported cabbageworms have not developed resistance to insecticides and their susceptibilities to different insecticides are still high(1,3,8). Obviously, the chemical control is still desirable in controlling this pest, We have no information concerning why the imported cabbageworms did not develop resistance, but it seems that the great migration ability of this species could mix population from different regions. Whether this genetic dilution has relieved the insecticide pressure is an interesting subject for the future study.

The cabbage loopers usually stay and feed on the foliage just as the importd cabbageworms, and should have similar opportunity in receiving the insecticide sprays, but the cabbage loopers are insensitive to both mevinphos and carbofuran. Mevinphos was not reported as a good insecticide for the cabbage looper(4,7,8,11), and the ineffectiveness of carbofuran in the looper control was also demonstrated by other investigators (7,9,10,11). These facts matched the results obtained in this study. In the synthetic pyrethroid tests, both cabbage looper and imported cabbageworm have similar sensitivities to fenvalerate except higher dosage of permethrin is needed for the looper control than that for the imported cabbageworm.

The test results indicated that tobacco cutworm was capable of developing resistance to fenvalerate, permethrin and mevinphos. The permethrin resistance occurred in three out of eight sampled regions and the mevinphos resistance was already prevailing in most of the sampled areas. Although the resistance to fenvalerate is still mild, it is much more wide-spread than that for permethrin. Judging from the susceptibilities of the most susceptible sample, fenvalerate, permethrin and mevinphos should be very effective if the tobacco cutworm had not developed resistance. The carbofuran resistance is more serious than other tested insecticides, because none of our sampled populations were really sensitive to carbofuran and the resistant ratios were also extravagant.

Hsi-hu is a region where vegetables constantly grows with heavy insecticide application, and the tobacco cutworm sampled from this area is highly resistant to all four tested insecticides. Practically, mevinphos and carbofuran were completely ineffective to control the cutworm in this area and permethrin has gradually lost its effectiveness. An interesting fact is that the most susceptible tobacco cutworm population was collected from an intensively cultivated vegetable field in Yangming mountain region. The low resistance may result from the polyphagous nature of this pest, which are not necessarily living within the vegetable growing area. The vast population in the mountain vegetation can constantly intermingle with the survivors from insecticide sprays and hence relieve the selection pressure.

Conclusions drawn from this investigation are that the synthetic pyrethroids are still effective in controlling the three studied pest species. The efficiencies of organophosphorus and carbamates are still good for the imported cabbageworm control but need to be re-evaluated in the cabbage looper and the tobacco cutworm. Third, the tobacco cutworm is definitely developing resistance to insecticides in many intensively cultivated regions.

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十字花科蔬菜三種鱗翅目害蟲抗藥性之探討[1]

周桃美　高靜華　鄭　允[2]

摘　要

本省歷年來蔬菜之蟲害保護工作多仰賴殺蟲劑，以致近年來害蟲相較趨於單純，但使用藥劑時，常有效果減退之現象發生。查其原因，可能係害蟲已對常用殺蟲劑產生不同程度之抗藥能力，小菜蛾，*Plutella xylostella* (L.)，即是一已經證實且抗藥問題極嚴重之十字花科蔬菜害蟲。此外，在十字花科蔬菜上經常發生的鱗翅目害蟲尚有紋白蝶，*Pieris rapae* Boisduval、斜紋夜盜 *Spodoptera litura* Fabricius及擬尺蠖 *Trichoplusia ni* Hübner。為瞭解後三種害蟲是否亦對殺蟲劑產生某種程度之抗藥力，乃進行本研究。

研究結果發現，本省各地採得之紋白蝶對四種常用殺蟲劑，美文松 (Mevinphos)、加保扶 (Carbofuran)、百滅寧 (Permethrin) 及芬化利 (Fenvalerate)，均極為敏感，無抗藥性產生之跡象，因此利用化學藥劑防治紋白蝶，仍為經濟可行而無抗藥性顧慮之防治方法。而擬尺蠖則對美文松、加保扶均不甚敏感，根據美、加地區之試驗結果報導，上述兩種藥劑對擬尺蠖之防治效果亦不甚良好；所測得之芬化利及百滅寧對擬尺蠖則無優良殺除效果。就斜紋夜盜而言，在所採得樣品中已明顯地發現，某些蔬菜密集生產地區之斜紋夜盜已經對常用殺蟲劑產生極高之抗藥性，溪湖地區即為明顯之例證，該樣品較敏感品系對加保扶、美文松之抗藥力分別高出79倍及63倍，對合成除蟲菊精類殺蟲劑亦有輕微之抗藥性。斜紋夜盜對不同殺蟲劑產生之抗藥程度，依地區有甚大之差異，但一般而言除蟲菊精類仍有相當好的防治效果；約有半數取樣地區之斜紋夜盜已對美文松產生中等程度以上之抗藥性；而加保扶之防治效果已明顯地消退。本研究之結論為：暫時使用合成除蟲菊精類殺蟲劑，仍為防治此三種鱗翅目害蟲之通用辦法；若採用有機磷劑或氨基甲酸鹽劑作為防治藥劑時，必須密切注意該地區此等害蟲抗藥性之發展。

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草莓葉蟎之生態研究[1]

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摘要：本研究於民國67年至70年在本省苗栗縣大湖鄉完成三期作草莓葉蟎之生態研究。每週或隔週取樣調查，計發現6種葉蟎爲害草莓，其中以神澤葉蟎（*Tetranychus kanzawai* Kishida）和二點葉蟎（*T. urticae* Koch）最爲重要，民國69年以前，神澤葉蟎居優勢，70年二點葉蟎棲羣激增，取代神澤葉蟎之優勢地位。三年間，葉蟎棲羣之增長均始於1至2月間，其棲羣高峰期：67—68年期作爲4月中旬，68—69年期作爲4月上旬，69—70年期作爲3月下旬，葉蟎類密度分別爲225，444及502隻／複葉，此後棲羣密度迅速下降至5隻／複葉以下，同時發現葉蟎之天敵7種，而以捕植蟎（*Amblyseius* spp.）與小黑隱翅蟲（*Oligota cviformis*（Casey）爲主要者，其棲羣高峰出現於3月上旬至4月下旬間，但密度均低，甚少超出1隻／複葉。總括而言，葉蟎棲羣密度之增長及急速下降主要受雨量及相對濕度之影響，一種眞菌病似爲後期葉蟎密度驟降主因之一。

草莓（*Fragaria chiloensis* var. *ananassa* Duch）爲極賦潛力集約栽培高價果菜，在結果期間，葉蟎常猖獗發生，爲草莓生產之主要問題。美國南加州記載爲害草莓之葉蟎有六點葉蟎（*Eotetranychus sexmaculatus* (Riley)），柑桔葉蟎（*Panonychus citri* (McGregor)），赤葉蟎（*Tetranychus cinnabarinus* (Boiduval)）及二點葉蟎（*T. urticae* (Koch)）等四種，其中以二點葉蟎最普遍而嚴重[8]；以系統性殺蟲劑 Phorate (Thimet) 處理土壤，可顯著抑制二點葉蟎發生，並減低因葉蟎爲害之產量損失達25%以上[9]；經研究發現二點葉蟎在每 cm^2 葉上經15蟎日（15 mitedays/cm^2），可使草莓之蒸散作用減低42%，若經50蟎日爲害，則光合作用降低60%[13]；另以殺蟎劑控制法，使草莓造成不同密度二點葉蟎之爲害，結果發現每小葉累積達 6,000蟎日時，才對產量及果實大小具顯著影響[12]；進一步研究獲得結論，若二點葉蟎提前發生，每小葉累積至3,200蟎日時，可顯著降低其光合作用效率，再累積達7,600蟎日時，可顯著減低每株之總產量，每小葉累積至 9,900蟎日後，則草莓果數及大小均顯著減少。若二點葉蟎延緩發生時，草莓則可忍受較高蟎日之爲害[14]。南加州夏作草莓對二點葉蟎之經濟危害水平訂爲每小葉50隻；北加州訂爲每小葉5隻即需防治[12,2]；學者發現大水災對二點葉蟎影響不大，然對天敵棲羣影響極大[11]；經試驗證明，二點葉蟎在某時期突然棲羣急驟下降，是其分散遷移之故[3]；二點葉蟎在南加州周年發生二明顯高峰，第一高峰在5月，第二高峰在9月，天敵有六點薊馬（*Scolothrips sexmaculatus* Pergande），捕植蟎類（Phytoseiids），小黑瓢蟲（*Stethorus* spp.）及花椿象（*Orius* spp.）等[10]；學者更發現不同草莓品種對二點葉蟎具有不同程度之抗性，進一步又發現草莓在春秋及初夏對葉蟎具誘引作用，但至7、8月則相反，至9月又回復其誘引力，至10、11月又轉變爲無誘引力[4]。

本省草莓栽培已有二十多年歷史、栽培方式、品種及氣象條件均與國外不同，其蟎害全憑農民之經驗施藥防治，但害蟎體極微小，均棲於葉背爲害，初期葉面不易見其爲害狀，待可見其爲害狀時採

1.臺灣省農業試驗所　研究報告第1175號，本研究爲行政院國家科學委員會 67B-0409-08(07)，69B-0409-03(02)，70-0409-B055-02及71-0409-B055-01等補助計畫之一部份。

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取防治措施已經太遲，況且每年發生時期均不固定，農民極難適時予以有效防治，筆者等有鑑於此，乃從事草莓葉蟎發生種類、發生時期、發生狀況與象氣因子之相關性及其天敵種類及發生狀況之調查與研究，經三年之累積資料，綜合報告如下，可供草莓葉蟎防治及將來進一步研究之參考。

材料與方法

葉蟎及其天敵之發生消長調查，係於苗栗縣大湖鄉之一固定草莓田進行，經三年定期調查（民國67—68年和68—69年爲每二周調查一次，69—70年爲每周調查一次），另在臺中縣霧峰鄉本所農場一年（69—70年）調查，草莓田面積各約 1 分地，均勻標定10取樣畦，全期未施用藥劑，定期摘取較底層之葉片，每畦隨機採摘10枚，共 100枚，至實驗室以雙管立體顯微鏡檢查葉蟎種類及各期數量與天敵種類及數量，種類鑑定需先製作標本，蟎類以 Hoyer's medium 製成玻片標本，經標記後放入 45°C 之定溫箱內，經 1 周之烘乾及透明，即可在顯微鏡下鑑定；薊馬、癭蠅類亦可用上法製成玻片標本；瓢蟲類則將雄蟲解剖，取出其外生殖器，仍以 Hoyer's medium 製成標本；隱翅蟲則浸於70%酒精內長期保存，在雙管立體顯微鏡下解剖而鑑別之。而草莓栽植期之每日氣象因子如溫度、相對濕度及雨量均由蠶業改良場大湖分場提供。

結果與討論

一、草莓葉蟎之種類及其棲羣動態：經三年於苗栗大湖及一年在臺中本所之調查，計發現爲害草莓之葉蟎有神澤葉蟎（*Tetranychus kanzawai* Kishida）（圖 1 — 1），二點葉蟎（*T. urticae* (Koch)）（圖 1 — 2），赤葉蟎（*T. cinnabarinus* Boud.），柑桔葉蟎（*Panonychus citri* McGregor)），裂爪葉蟎（*Schizotetranychus* sp.）及卵圓僞葉蟎（*Brevipalpus obovatus* Donnadiau）等 6 種。苗栗大湖第 1 年期作（67—68年）調查，神澤葉蟎佔絕對優勢，全期出現相對密度約佔85%，二點葉蟎與柑桔葉蟎約佔10%，其他 3 種葉蟎合計僅佔 5 %左右；第 2 年期作（68—69年）仍以神澤葉蟎佔優勢，約佔80%，然二點葉蟎已顯著增加，約佔相對密度之10%，其他種類個體密度與上年者無顯著變動；第 3 年期作（69—70年）情況大變，苗栗大湖草莓上之葉蟎中，二點葉蟎突然獗起成爲主流，取代了神澤葉蟎之優勢地位，其相對密度竟佔85%以上，神澤葉蟎密度落居次席，約僅佔10%，而於臺中本所調查一期作（69—70年），神澤葉蟎出現密度比仍高達85%以上，二點葉蟎仍爲偶見之次要害蟎。苗栗大湖第三年期作葉蟎相之劇烈改變，筆者認爲似受下列三因素之影響：(一)二點葉蟎爲外侵之害蟎，最早於高海拔之梅峰被筆者發現，由於此蟎對溫度適應範圍極廣，寄主植物又多[7]，故不出三年，迅速自高海拔地區遷移（藉風力或人爲因素）擴張而達低海拔之苗栗大湖地區；(二)二點葉蟎對多種殺蟎劑抗性甚强，而神澤葉蟎抗藥性較低（筆者等未發表資料），在殺蟎劑之選汰下，二點葉蟎便逐漸佔居優勢；(三)二點葉蟎爲新近侵入本省之害蟎，本省土產天敵對其捕食力較低，反之對神澤葉蟎之捕食力較强大[6]。而目前（72年）二點葉蟎已經分布全省各地，凡草莓種植地區所出現之葉蟎，皆以二點葉蟎爲主（筆者未發表資料），似可映證以上之推論。

本省草莓一般均在10月種植，12月開花隨之結果，結果期可自 1 月至 5 月，盛產期爲 2 至 4 月間，而葉蟎之發生至 1 月底即有顯著增加，2 月初密度突然上升，3,4月爲其發生密度之高峰期，4 月之後，雨量逐漸增加，相對濕度上升，促使一種寄生葉蟎之眞菌（尚未定名）大量發生，使葉蟎棲羣驟然下降（圖 1），此期草莓葉片幾乎全遭葉蟎爲害，呈現枯黃狀，且草莓生育亦達晚衰期，此期葉蟎之驟減，對草莓之生機和產量並無助益。由圖 1 明顯看出三年間葉蟎發生密度雖有不同，但其發生盛期均與草莓之生育盛期相吻合，在三年期作間，溫度相差不多，但相對濕度各年均呈明顯差異；67—68年期作之全期相對濕度均高，均在75—88%之間，12月至 2 月間雨量最高，該年葉蟎發生密度至 2 月底才顯著上升，密度之高峰期至 4 月間出現，葉蟎密度爲 225頭／複葉，由於發生時期延後，葉蟎在草莓上繁殖之總代數減少，故其在全期發生密度爲三年中最低者；68—69年期作間相對濕度較上

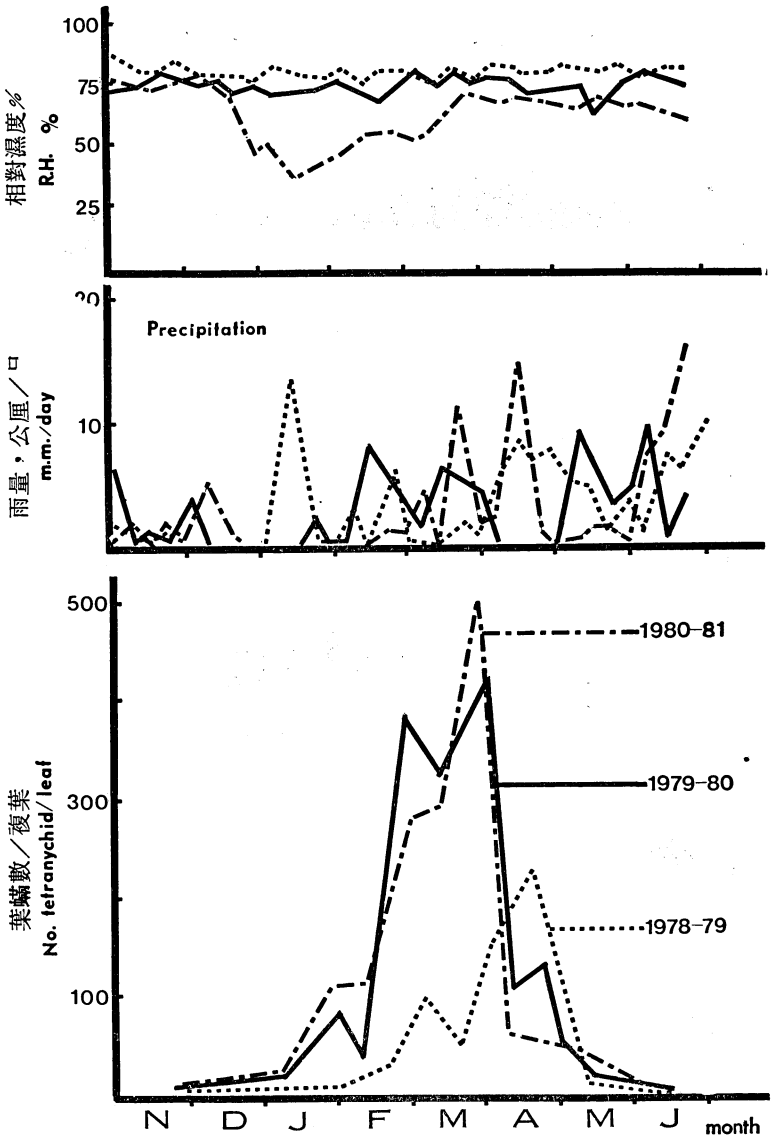


圖1. 草莓葉蟎在三年期作中棲羣之動態與氣象因子之關係（苗栗大湖）

Fig. 1. The population fluctuation of spider mites on strawberry (Tahu)

年期者爲低，在68—83%之間，該期作中12月間雨量甚低，故於1月中旬葉蟎密度便趨上升，至2月中旬葉蟎密度急劇上升，至4月上旬達最高峰，葉蟎密度高達 444頭＼複葉，此後便急速下降；69—70年期作間相對濕度較以往兩年顯著下降，自12月下旬至2月中旬雨量極少，於1月上旬相對濕度竟低達38%，全期相對濕度在38—76%之間，故此期葉蟎密度在1月上旬便急劇上升，2至4月上旬爲其密度之高峰期，3月下旬葉蟎密度竟高達 502頭＼複葉。由以上結果，似可說明雨量和相對濕度對草莓葉蟎發生有非常密切之關係，而在三年期作間，溫度變化不大，故溫度變化對葉蟎之影響似不若濕度之重要。草莓植株矮，葉片貼近土表，微氣候 (Microclimate) 因子當對草莓葉蟎影響極大，一般而言，愈近土壤表面，其相對濕度應愈高，又根據記載，美國佛州 (Florida) 之柑桔葉蟎，在高濕多雨季節常被一種蟲生菌（*Entomophthora* sp. ）寄生，寄生率可達30—90%[7]；然在美國加

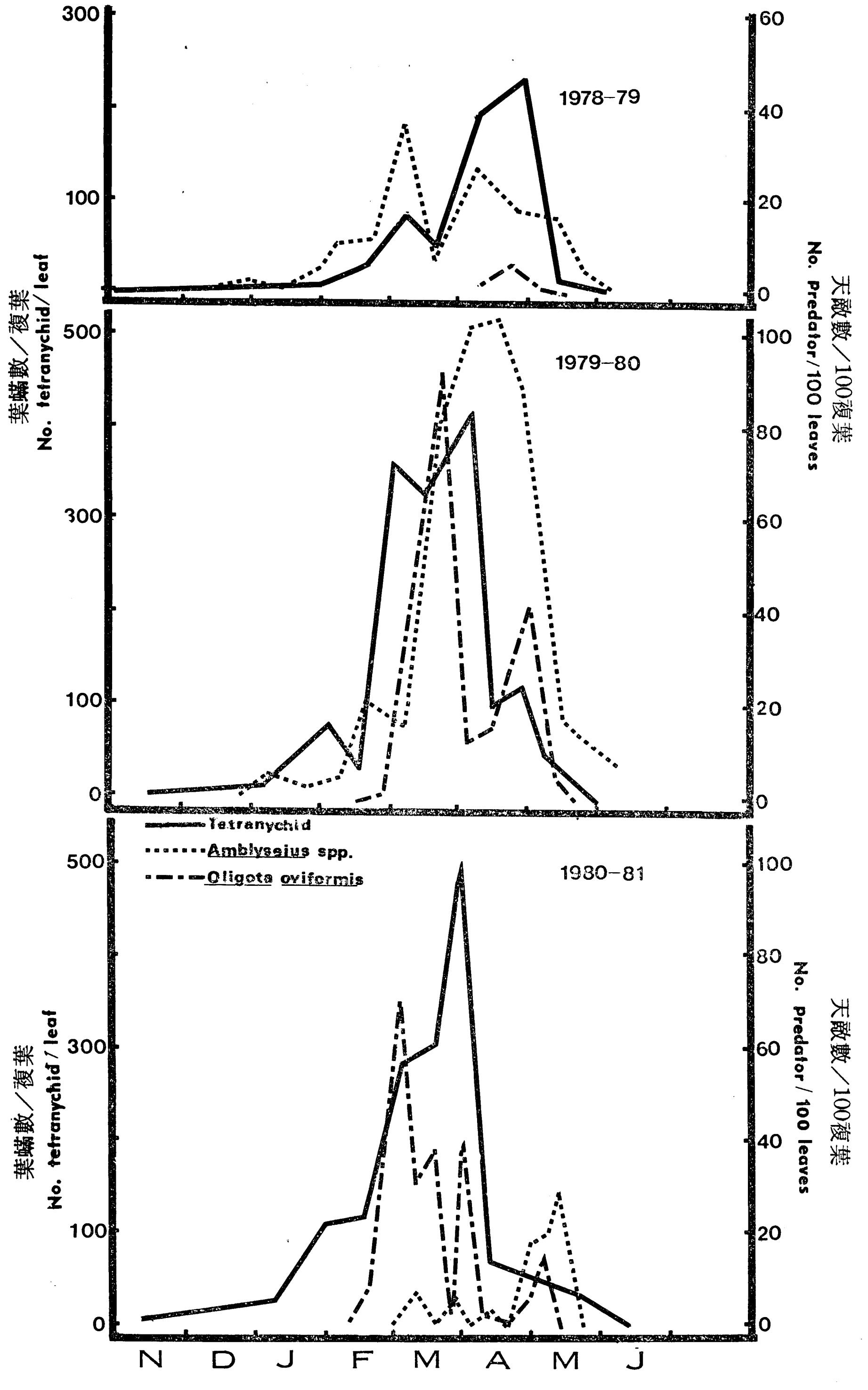
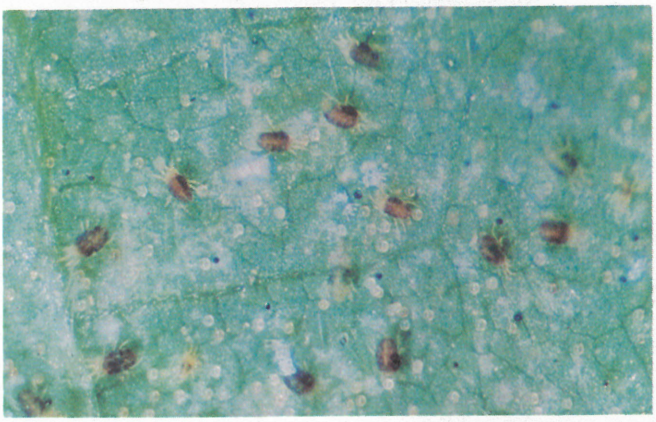


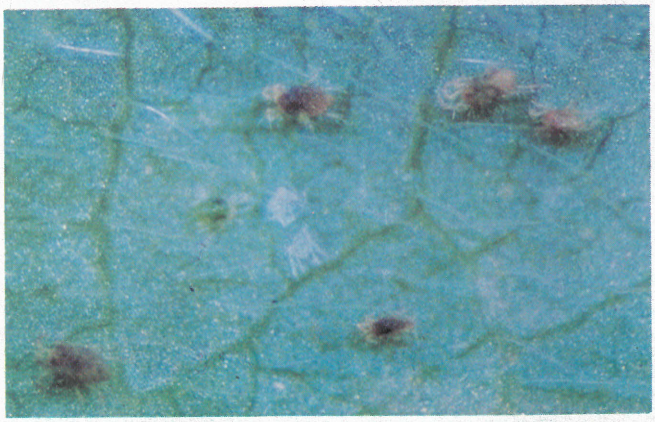
圖2. 三年期作中、葉蟎及其天敵棲羣之變動狀況（苗栗大湖）

Fig. 2. The population fluctuations of spidermites and natural enemics (Tahu)



1—1

1—2



1—3

圖 1、草莓之主要葉蟎及其被眞菌寄生情形

Fig. 1. The major spider mites of strawberry and spider mites infested by a fungus.

1—1. 神澤葉蟎 (Kanzawa spider mite, *Tetranychus kanzawai*)

1—2. 二點葉蟎 (Two-spotted spider mite, *T. urticae*)

1—3. 二點葉蟎被眞菌寄生情形 (Two-spotted spider mites infested by fungus)

州 (California)，柑桔葉蟎和六點葉蟎 (*Eotetranychus sexmaculatus* (Riley)) 則均未發現有眞菌寄生，似與氣候乾燥有關[7]；日本北海道豆類作物上曾發現一種尚未定名之眞菌寄生二點葉蟎 (Mori 氏未發表資料)。據筆者等調查記載，苗栗大湖草莓之葉蟎，均自 3 月中旬至 4 月上旬起遭一種眞菌寄生 (圖 1 — 3)，此與相對濕度及雨量之增高似有密切關係，顯與葉蟎棲羣迅速下降有關。

二、草莓葉蟎之天敵種類及其棲羣動態：經調查發現在草莓上捕食葉蟎之天敵，計有小黑隱翅蟲 (*Oligota oviformis* (Casey))，羅氏小黑瓢蟲 (*Stethorus loi* Sasaji)，六點薊馬 (*Scolothrips sexmaculatus* Pergande)，西方癭蠅 (*Arthrocnodax occidentalis* Felt.)，捕植蟎類 (*Amblyseius* spp.)，氈蟎 (Ascid mites) 及長鋏蟎 (*Cunaxa* sp.) 等七種 (類)，其中以捕植蟎類及小黑隱翅蟲發生較普遍。在捕植蟎中，長毛捕植蟎 (*Amblyseius longispinosus* (Evans)) 出現密度甚低，而其他種類均非本省主要之捕植蟎，因而未能發揮抑制葉蟎之功效，小黑隱翅蟲因化蛹於土中，易受雨水或其他昆蟲捕食的影響[1]，棲羣密度未能達有效控制葉蟎之標準，其他天敵均屬偶見，並不重要。一種尚未定名之眞菌病 (圖 1 — 3) 於 4 月之後普遍發生，對後期草莓葉蟎棲羣密度之壓抑似具決定性影響。

在 7 種 (類) 天敵中，以捕植蟎和小黑隱翅蟲較普遍，前者在草莓生育全期均有出現，其棲羣均隨葉蟎之增高而上升，然至發生盛期，其密度仍少超過 1 頭＼複葉；小黑隱翅蟲出現於 2 月後葉蟎密度增高之時期，但密度增長緩慢 (圖 2)，故對葉蟎棲羣增長之抑制能力甚低。天敵棲羣密度過低之原因，推測可能與以往多年全面施用殺蟎劑防治葉蟎及噴洒巴拉松防治葉芽線蟲密切相關，二者之中以巴拉松對天敵之毒性最爲劇烈[5]。

爲防止本省草莓不受葉蟎之危害，1 至 3 月爲防治之重要時期，而在此期間又以 1 月上旬爲實施生物防治葉蟎之關鍵時刻，因此時葉蟎之密度開始緩慢上升，但密度仍低，對草莓尚未造成損害，此期若釋放少量有效天敵，可以達到長期防治葉蟎之效果，且自 1 月開始正值結果之旺季，如運用生物防治將不致發生藥劑防治之殘毒問題。

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An Ecological Study of Spider Mites on Strawberry in Taiwan[1]

Paul K. C. Lo, C. C. Ho, and C . K. Tseng[2]

Summary

An ecological study of spider mites and their native predators was conducted on strawberry fields in Tahu, Miaoli, Taiwan with populations being survey at weekly intervals during 1979—81. Six spider mites i. e. *Tetranychus kanzawai* Kishida, *T. urticae* (Koch), *T. cinnabarinus* Boud., *Panonychus citri* (McGregor), *Schizotetranychus* sp. and *Brevipalpus obovatus* Donnadiu were found, and *T. kanzawai* and *T. urticae* were recognized as the dominant pests. From 1977 to 1980, *kanzawai* mite was the predominating species, but since 1981, the two-spotted spider mite had become the dominant one. Populations of the spider mites in those three years usually started to increase in the period of January to February and reached peaks of 225, 444, and 502/leaf on medium of April(1978—79), early of April(1979—80), and late of March (1980—81), respectively. The population then declined abruptly to less than 5 mites/leaf. Seven predators i. e. *Oligota oviformis* (Casey), *Stethorus loi* Sasaji, *Arthrocnodax occidentalis* Felt, *Scolothrips sexmaculatus* Pergande, *Amblyseius* spp., *Cunaxa* sp., and Ascid mites were present, *Amblyseius* spp. and *Oligota oviformis* were the dominant species. Their populations usually reached a peak of no more than 1/leaf between early March to late April. It was concluded that the mite populations on strawberry declined abruptly primarily due to the high precipitation, high relative humidity and a fungal disease.

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